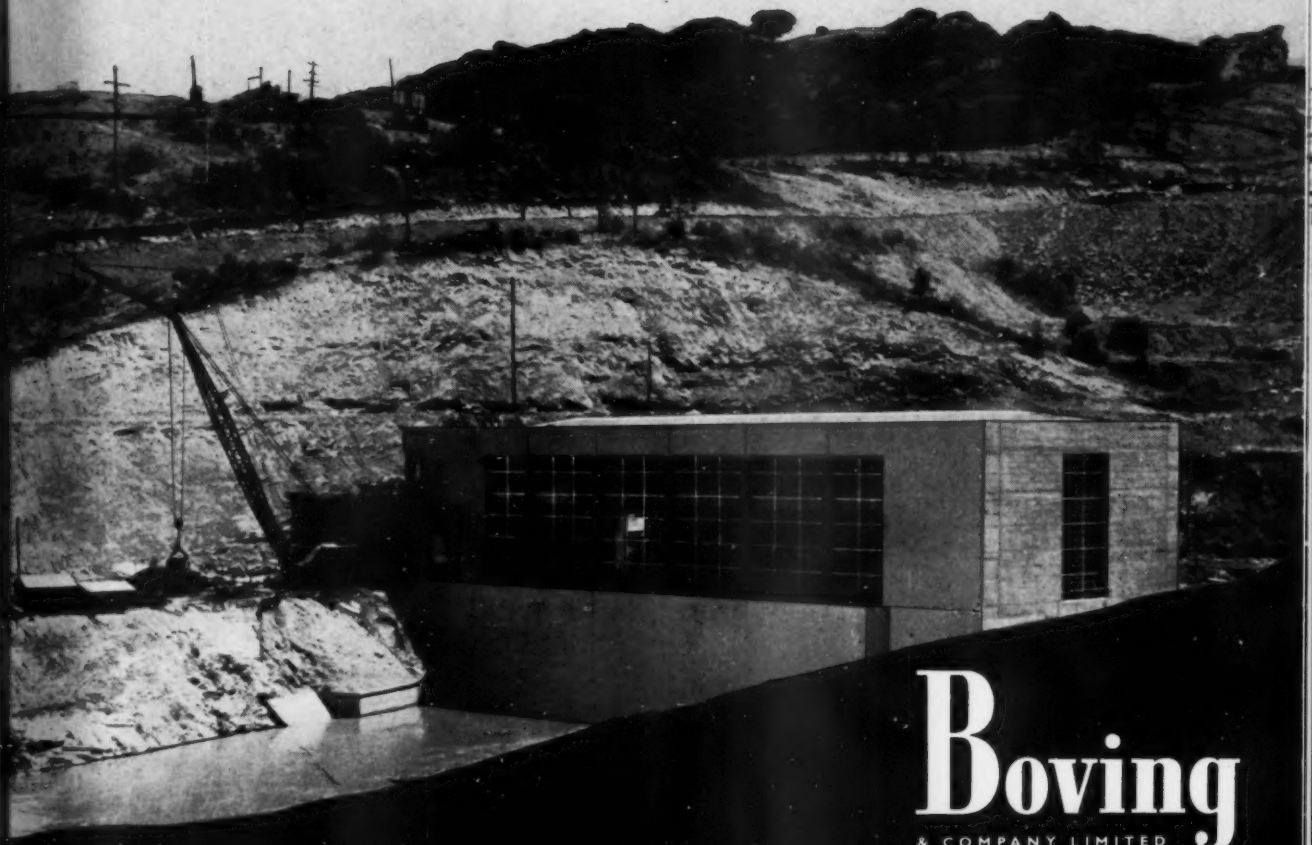
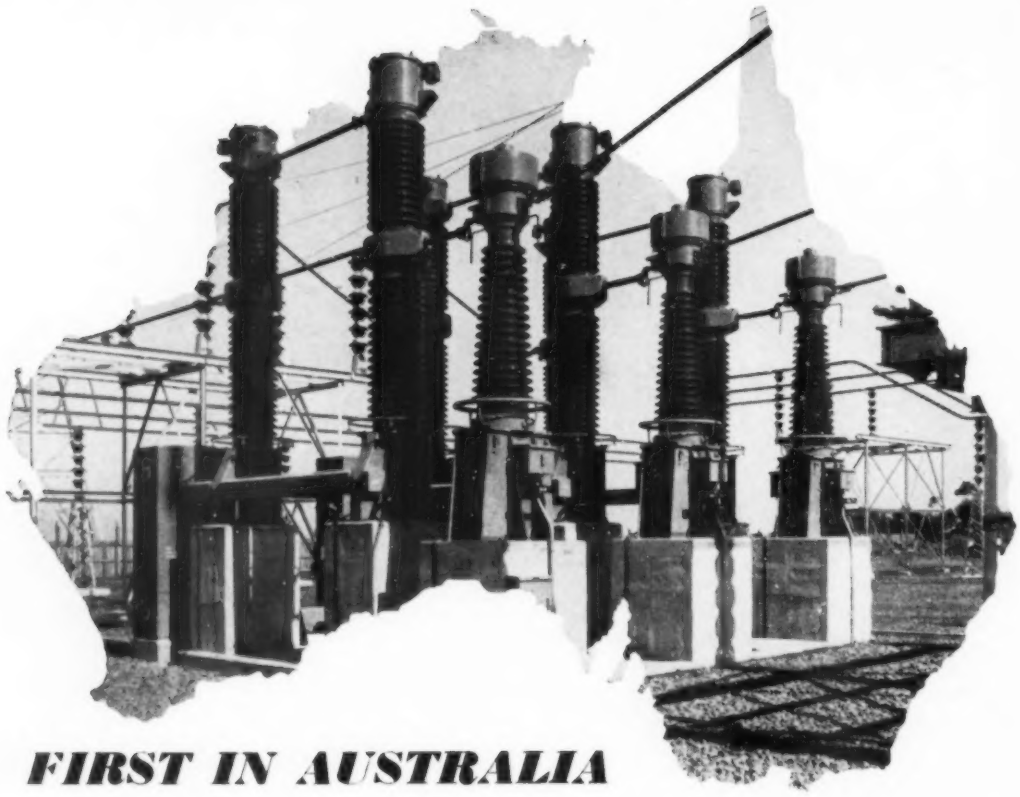
Eildon Power Station

The State Electricity Commission of Victoria have selected Boving Vertical Francis Turbines for their new Power Station at Eildon.
Two Units will be installed, each rated at 82,100 h.p. at 150 r.p.m., operating under a head of 230 ft.



Boving
& COMPANY LIMITED

WATER POWER ENGINEERS



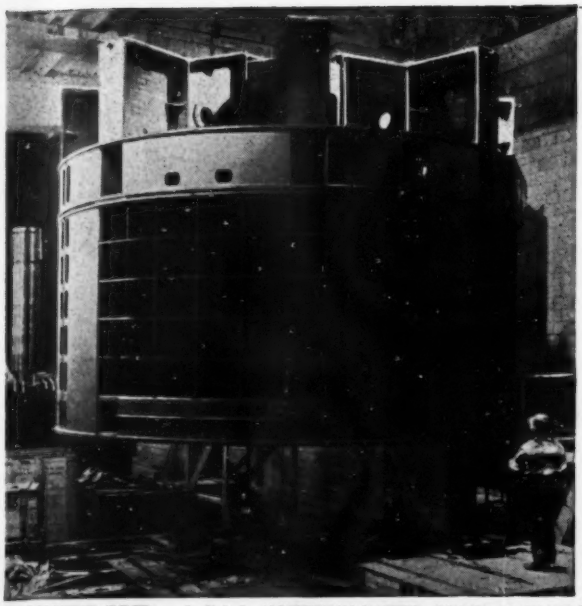
FIRST IN AUSTRALIA

commissioned and energised at 220-kV

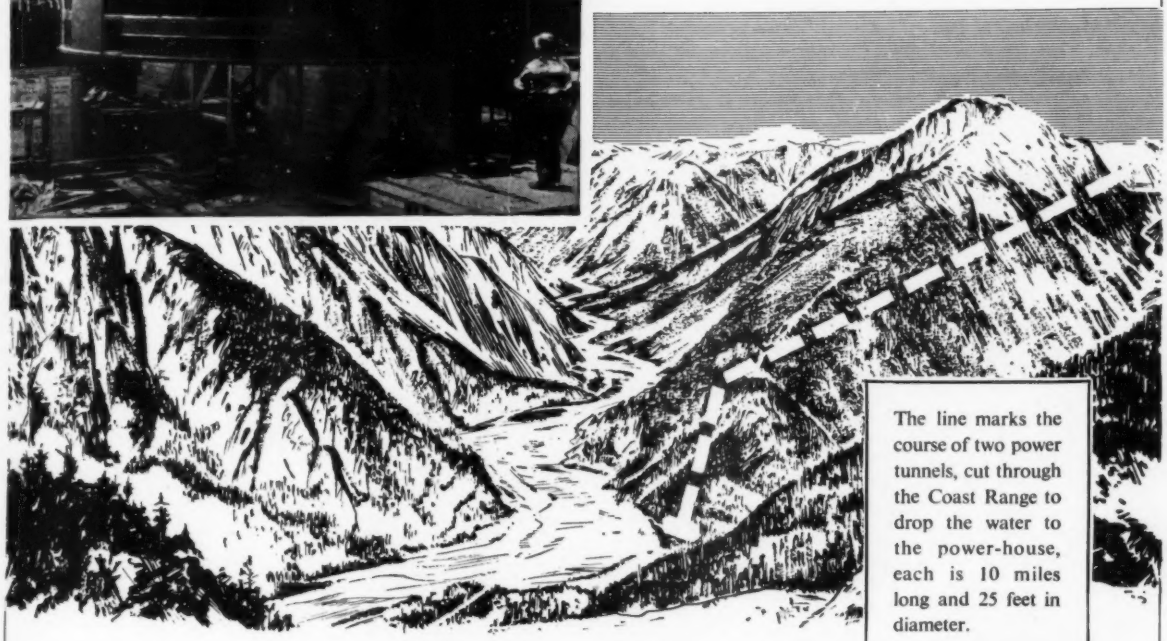
The first of a number of 220-kV 5000-MVA small-oil-volume circuit-breakers in normal 220-kV service at the Thomastown Terminal Station of the State Electricity Commission of Victoria controlling the incoming 220-kV line from the KIEWA Hydro-Electric Stations.

Reyrolle

A REYROLLE & COMPANY LIMITED • HEBBURN • COUNTY DURHAM • ENGLAND



A POWER HOUSE IN A MOUNTAIN



The line marks the course of two power tunnels, cut through the Coast Range to drop the water to the power-house, each is 10 miles long and 25 feet in diameter.

The Kitimat project of the Aluminium Company of Canada plans eventually for an annual production of 500,000 metric tons of aluminium, requiring electrical power equivalent to 1,650,000 h.p. The initial stage of this scheme, comprising 450,000 h.p. is completed. The ENGLISH ELECTRIC Company's contribution to this first stage is a 105,000 kVA alternator. This is one of the largest water-turbine-driven alternators built in Great Britain, and was delivered well ahead of schedule.
A 213,000 kVA bank of transformers has been supplied by the ENGLISH ELECTRIC Company of Canada.

'ENGLISH ELECTRIC'
hydro-electric equipment

THE ENGLISH ELECTRIC COMPANY LIMITED, QUEENS HOUSE, KINGSWAY, LONDON, W.C.2
Hydro-Electric Department, Stafford
WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON
HE. 1734

This 2,680′ Bridge River, British Columbia, Dominion of Canada, penstock was built by B. C. Electric. Of 75⅝″ O. D. steel pipe, it is Dresser-Coupled in 40′ lengths with maximum slope of 39½°. Uncovered except for one intermediate tunnel, it tested completely leakproof at 1000 psi.

6 ft. 3 and TROUBLE-FREE at 1000 psi

B. C. Electric installs 4th Dresser-Coupled penstock

Convinced of the advantages of Dresser Couplings, the B. C. Electric Company, since 1948, has installed four 100 per cent Dresser-Coupled penstocks at Bridge River, British Columbia. On all four projects, the use of Dresser Couplings resulted in faster completion of the line and assured permanently tight, maintenance-free joints. This meant earlier revenue from plant operation . . . uninterrupted service to power consumers.

Throughout the world, leading engineers and contractors recognize the superiority of the Dresser pipe joining method — permanent tightness, flexibility, simplicity, strength and economy.

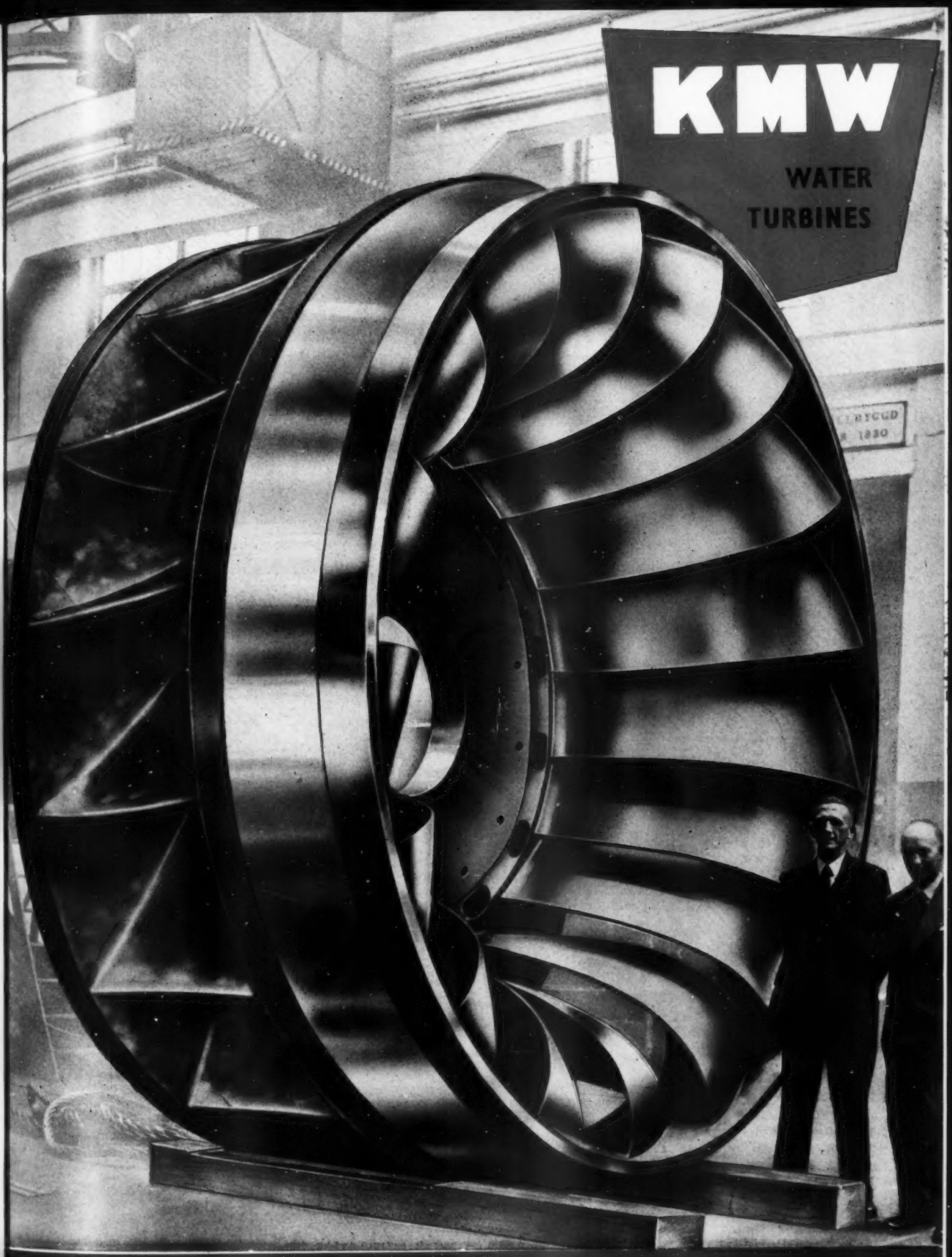
Even highest pressure penstocks are faster and easier to install when Dresser Couplings are used. The need for special skills and expensive equipment is minimized. In many cases, a field crew of a few men can cut construction time from months to weeks through the use of Dresser Couplings. Work proceeds in any weather with wrenches the only tools needed.

Where required, high tensile steel permits thinner pipe walls and lower pipe weights. This means easier handling. In some cases, up to 25 per cent in weight is saved.

But a Dresser-Coupled penstock's most important advantage is permanence . . . it stays bottle-tight for life. The resilient gaskets built into every coupling assure positive sealing, eliminate expansion-contraction problems, permit joint deflections so the penstock may follow the natural contour of the right of way.

For your next penstock project, send for helpful, interesting engineering data on the successful and varied Dresser-Coupled steel penstock installations. Write Dresser Manufacturing Division, Bradford, Pa., U.S.A.

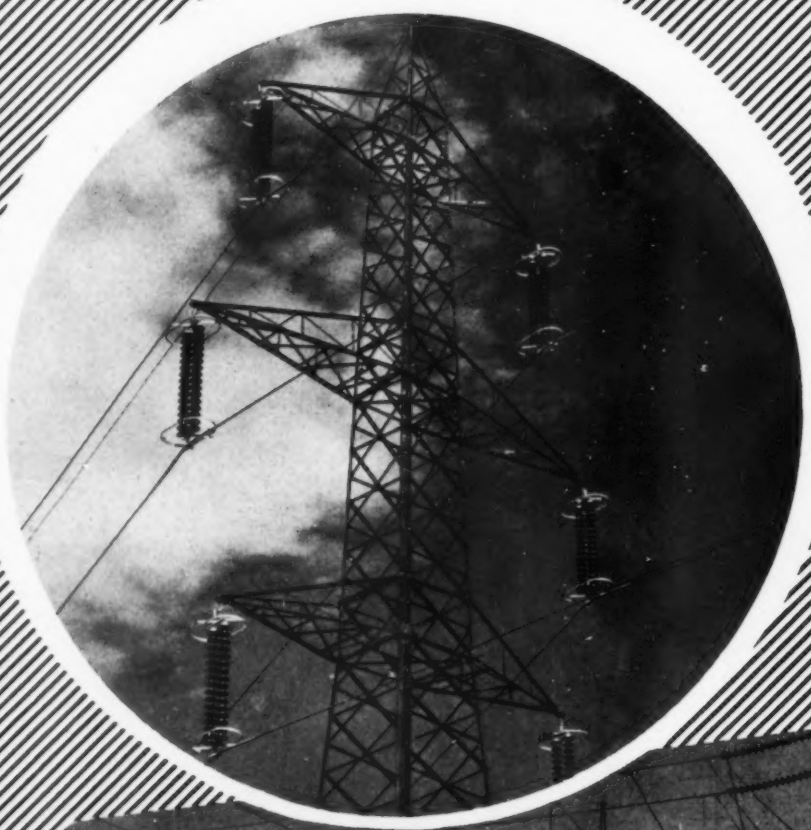
ONE OF THE DRESSER INDUSTRIES

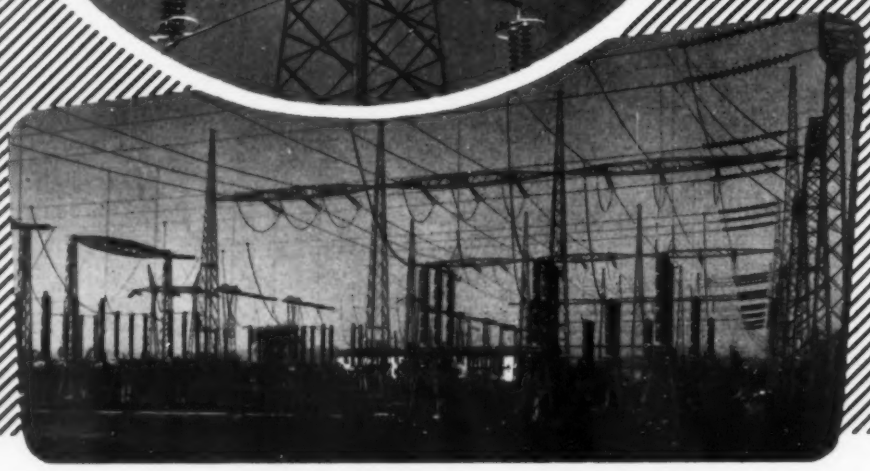


AKTIEBOLAGET KARLSTADS MEKANISKA WERKSTAD

KARLSTAD · SWEDEN

SALVI





3-230 kV Villa Valle-Cornegliano 4 Twin S.C.A. Conductor Transmission Line (Societa TERNI-Rome)

For 30 years Messrs. A. Salvi and Company, Milano, Italy, have specialized in the design and manufacture of complete equipment for Overhead Transmission Lines, including Compression Dead End Assemblies and Joints.
The Works of the Salvi Company are engaged exclusively in the production of high grade fittings for High Voltage Transmission Systems, up to and including voltages of 220/380 KV, and for all sizes of Copper, A.C.S.R. and Aluminium Alloy Conductors.

SOLE REPRESENTATIVES IN THE UNITED KINGDOM AND THROUGHOUT ALL DOMINION COUNTRIES (EXCEPT AUSTRALIA AND NEW ZEALAND) AND BRITISH COLONIES AND PROTECTORATES

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NEW HOLMAN IMPACT WRENCH

Roof bolting with the Holman Impact Wrench.

MINERS are finding this latest newcomer to the Holman Pneumatic Tool range an extremely useful aid in roof bolting, especially when used in conjunction with the famous Holman Dryductor Drill. Built to the high engineering standards of all HOLMAN tools, it is compact, light and easy to handle, transmitting the minimum of torque reaction to the operator. *It gives a more powerful turning effect than any other portable torque-type wrench.* Wherever time and money can be saved by speeding the tightening or removal of nuts and bolts there is a job for the Holman Impact Wrench. May we send full details ?

IMPACT WRENCH Size 404, powered by Holman Vane Type Motor. Suitable for ¾-in. heavy duty and 1-in. normal duty. Output Spindle takes 1-in. square drive chucks. Length 16 in. Weight 21 lb.

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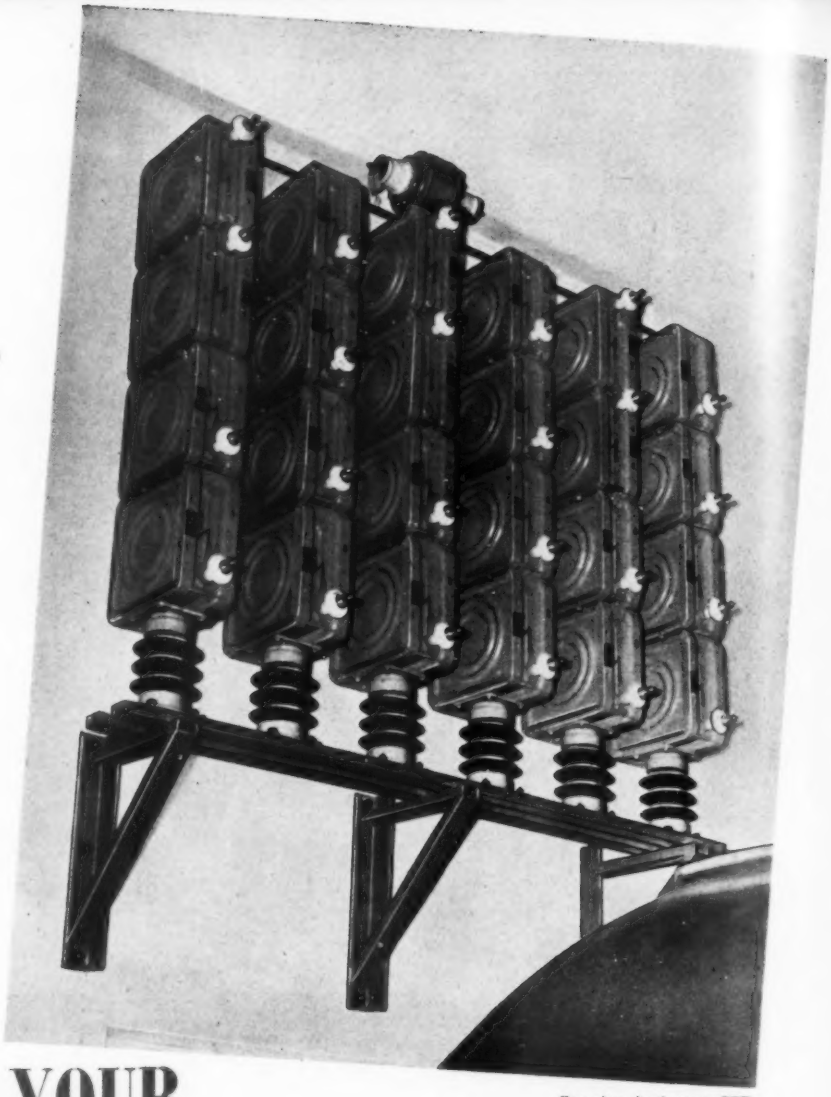
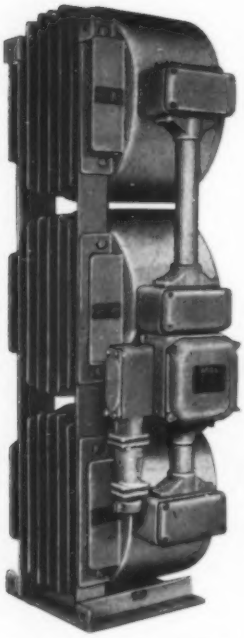
Are YOU penalized for reactive power consumption?



Capacitor bank type CTD, 480 kVAr, 6·, kV, 50 c/s, installed in a Norwegian pulp mill.



Capacitor type CTA, 87 kVAr, 400 V, 50 c/s mounted in frame for fixing to wall or floor. Note the ample terminal enclosure.

Is YOUR electrical equipment being overloaded?

There is an unabating increase in the demand for electric power and many power supply systems are being worked to the point of failure.

ASEA Capacitors furnish an expedient and inexpensive means of improving your power situation.

The capacitors are designed as standard units which can be built up into banks of requisite size. Banks may be enlarged by adding units, or the rating altered by transferring units from one bank to another, according to prevailing supply conditions.

Consult ASEA for expert advice on your power problems. Capacitors in all sizes for 230, 400, 440 and 500—550 V can be supplied from stock.

ASEA Capacitors

- ✱ **reduce all transmission losses**
- ✱ **improve voltage conditions in the supply mains**
- ✱ **permit higher active loading of generators, cables and transformers**
- ✱ **enable the power producers to supply more kilowatts**
- ✱ **entail lower costs for energy consumed**
- ✱ **obviate penalties for excessive consumption of reactive power and energy**
- ✱ **pay for themselves in a very short time merely by the reduction in penalties for reactive power**

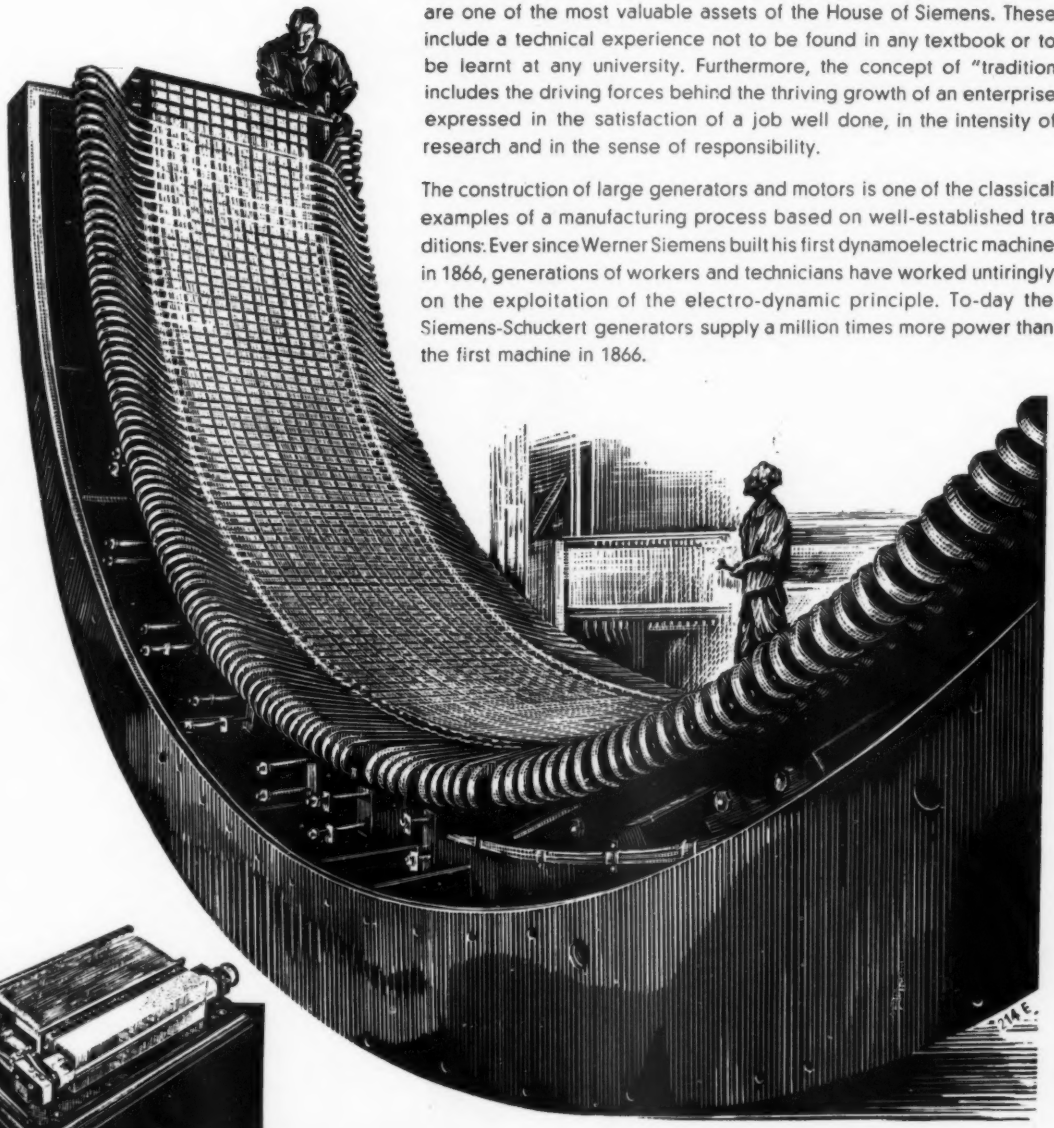
Västerås ASEA Sweden

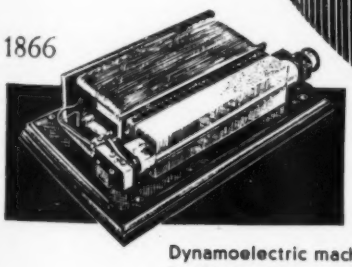
SIEMENS

Tradition - a living force

Sober statistics can never show the living forces of tradition which are one of the most valuable assets of the House of Siemens. These include a technical experience not to be found in any textbook or to be learnt at any university. Furthermore, the concept of "tradition" includes the driving forces behind the thriving growth of an enterprise, expressed in the satisfaction of a job well done, in the intensity of research and in the sense of responsibility.

The construction of large generators and motors is one of the classical examples of a manufacturing process based on well-established traditions: Ever since Werner Siemens built his first dynamoelectric machine in 1866, generations of workers and technicians have worked untiringly on the exploitation of the electro-dynamic principle. To-day the Siemens-Schuckert generators supply a million times more power than the first machine in 1866.





Dynamoelectric machine built by Werner Siemens in 1866

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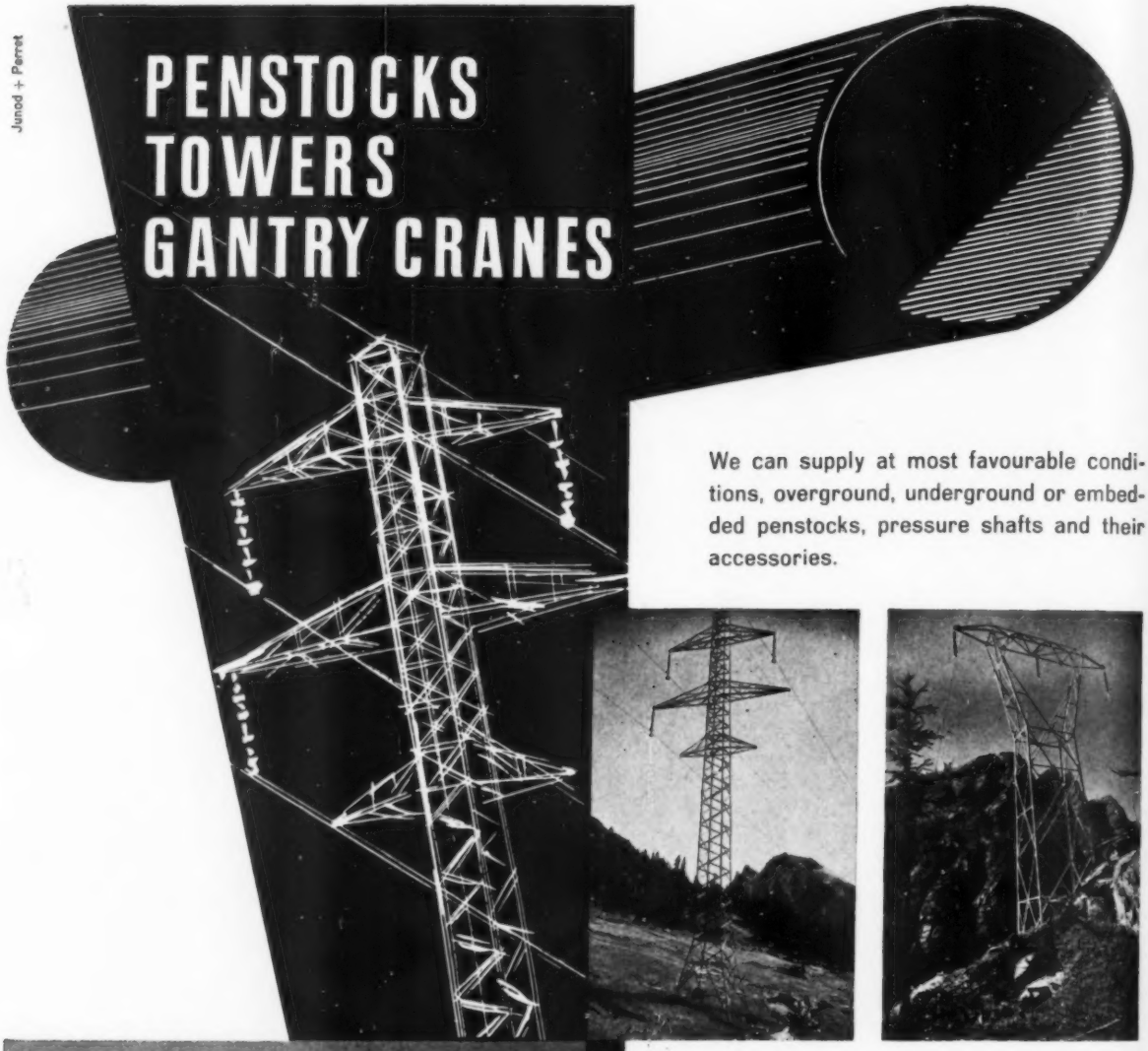
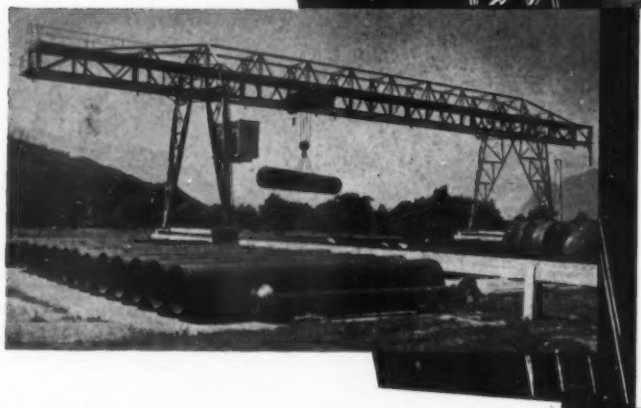
PENSTOCKS
TOWERS
GANTRY CRANES



We can supply at most favourable conditions, overground, underground or embedded penstocks, pressure shafts and their accessories.

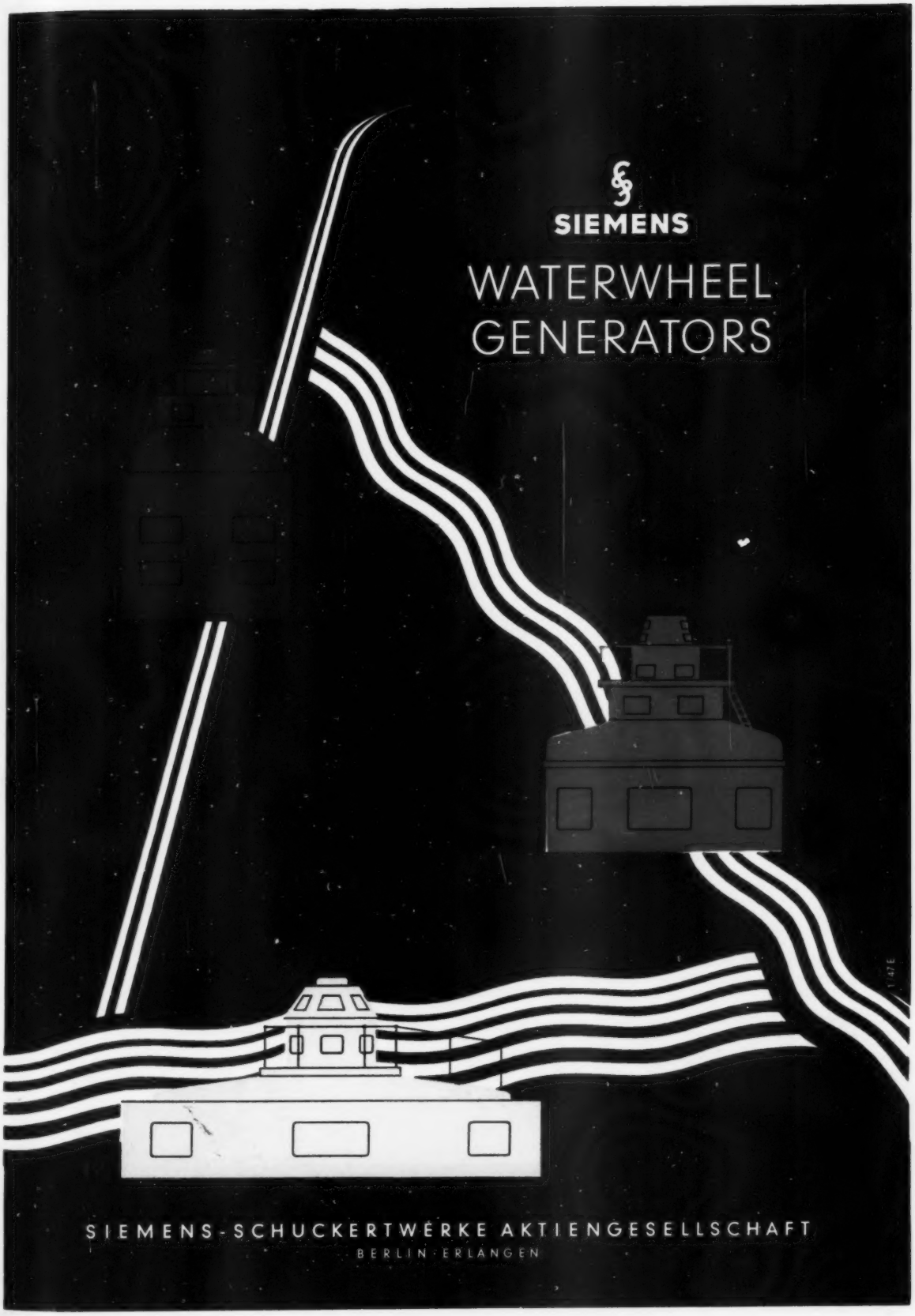
Towers for electric transmission lines, for teleferics or radio aerials.
Steel structures for buildings.
Reservoirs of any shape and dimensions.



Gantry crane, lifting capacity 3 to 25 tons, distance between rails 36 m., 2 overhangs of 12 m., total length 60 m.

giovanola

GIOVANOLA FRÈRES S. A., MONTHEY (VS) SUISSE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This post insulator was designed and manufactured by Bullers Limited to the requirements of the British Electricity Authorities specification for 275 K.V. Switchgear.

BULLERS LIMITED design and manufacture both porcelain and metal parts in their own works.

Enquiries are invited for porcelain insulators and fittings for any voltage and mechanical loading.

We specialise in :

Porcelain for general insulation.
Refractories for high-temperature insulation.
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Fittings for insulators and overhead lines, etc.

Height of post 116"
Cantilever strength 2,000 lb.
Dry withstand test 580 K.V.
Wet withstand test 520 K.V.

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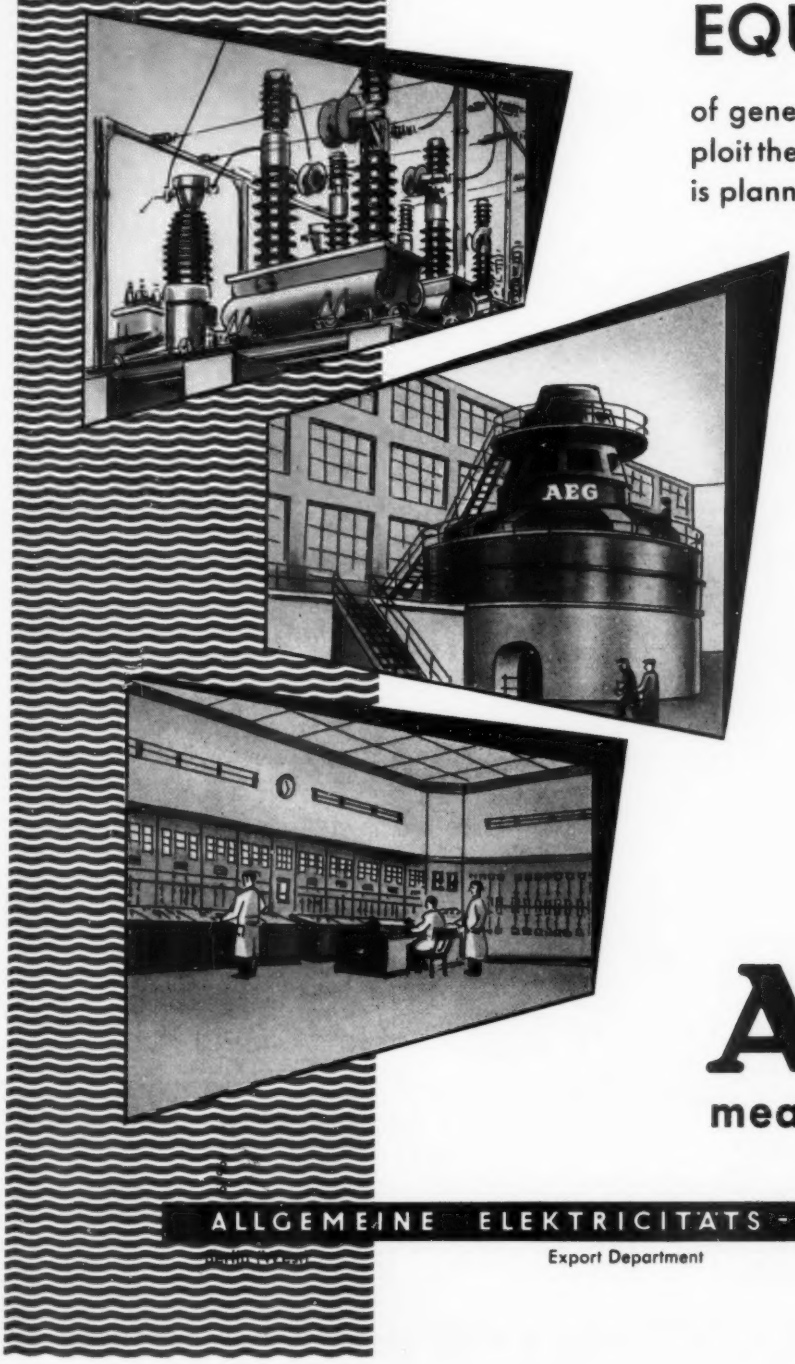
of generating stations to exploit the motive force of water is planned and built by AEG



Sixty years of steadily accumulating experience in research and construction work warrant a high degree of reliability in operation, and economy in performance, of AEG Hydro-Electric Installations.

AEG

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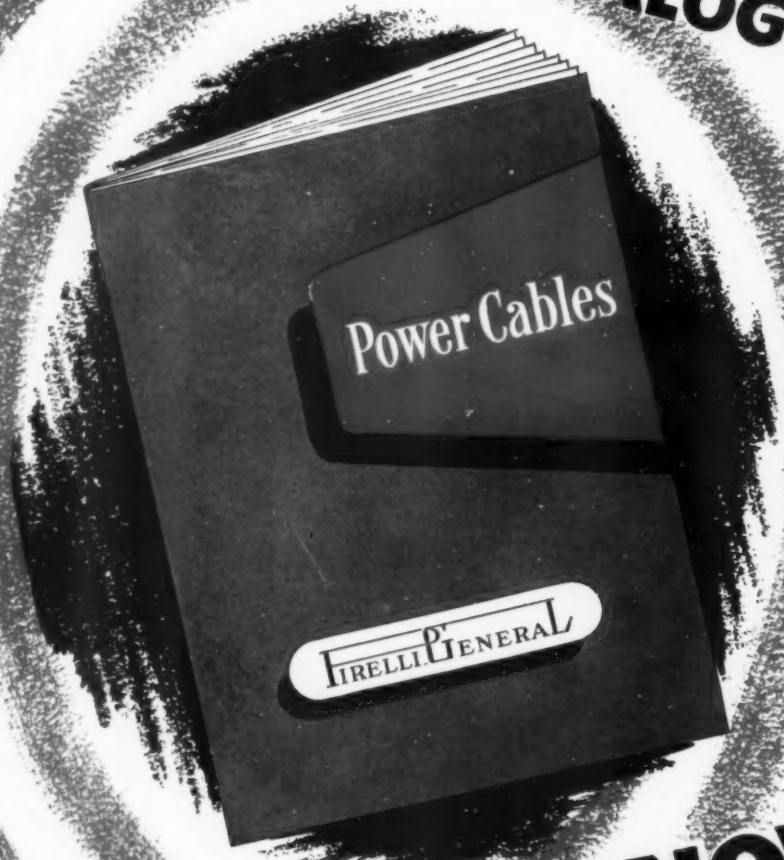

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The power cables referred to in this publication conform to B.S. 480: Part 1: 1954 which specifies paper insulated lead sheathed cables for 1,100 to 33,000 volt operation.

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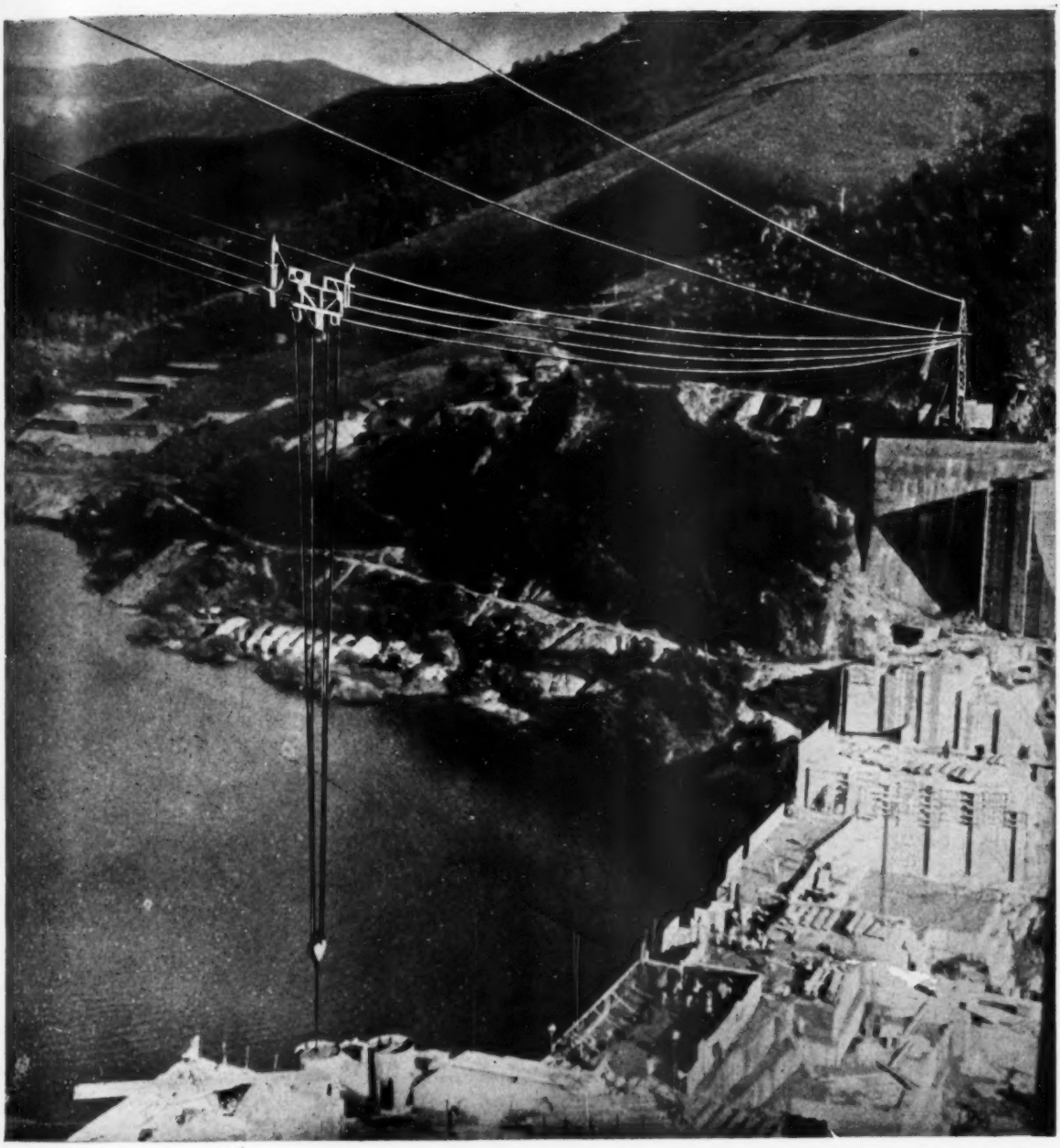

speeding dam construction in India

In India, where weather rules working time, hold-ups due to inefficient or inferior equipment can seriously hamper a construction programme. That is why so many projects in India, such as the Madupatty Dam pictured here, depend on Henderson Cableways for continuous handling of building materials. Low cost materials handling is the key to successful Civil Engineering in any part of the world—and wherever there is a Dam or Barrage, a Bridge or Viaduct to be built, Henderson Cableways will usually be the most practical means of construction.

Henderson

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The largest Overseas Transformer Contract ever received in the United Kingdom

FERRANTI
TRANSFORMERS
THIS TIME
FOR THE DALLES DAM U.S.A.

Ferranti Ltd. have received the largest overseas transformer contract ever to be placed in the United Kingdom.
The contract covers eighteen 63,000 kVA, 230 kV, single phase and three 63,000 kVA, 115 kV, single phase transformers for the U.S. Army Corps of Engineers Dalles Dam Project, Columbia River, on the borders of Washington and Oregon and is valued at $2,080,940 (£746,000).
It is the fifth contract awarded to Ferranti Ltd. by the U.S.A. in recent years and brings the total number of transformers supplied or under construction to 38 units of a total capacity of 1,972,000 kVA, and a value of $3,827,000 (£1,366,785).

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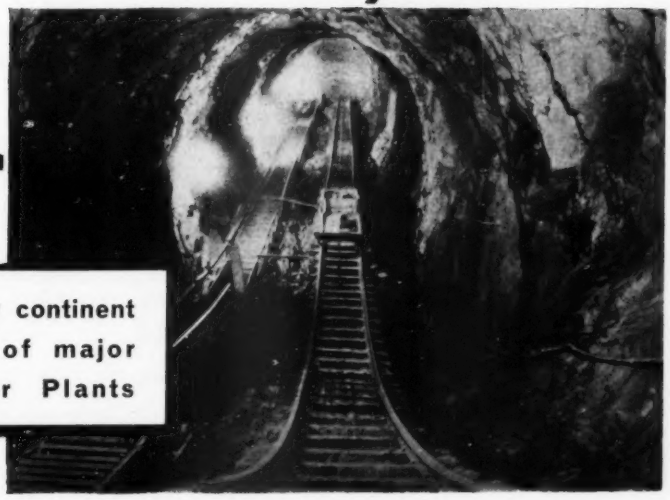
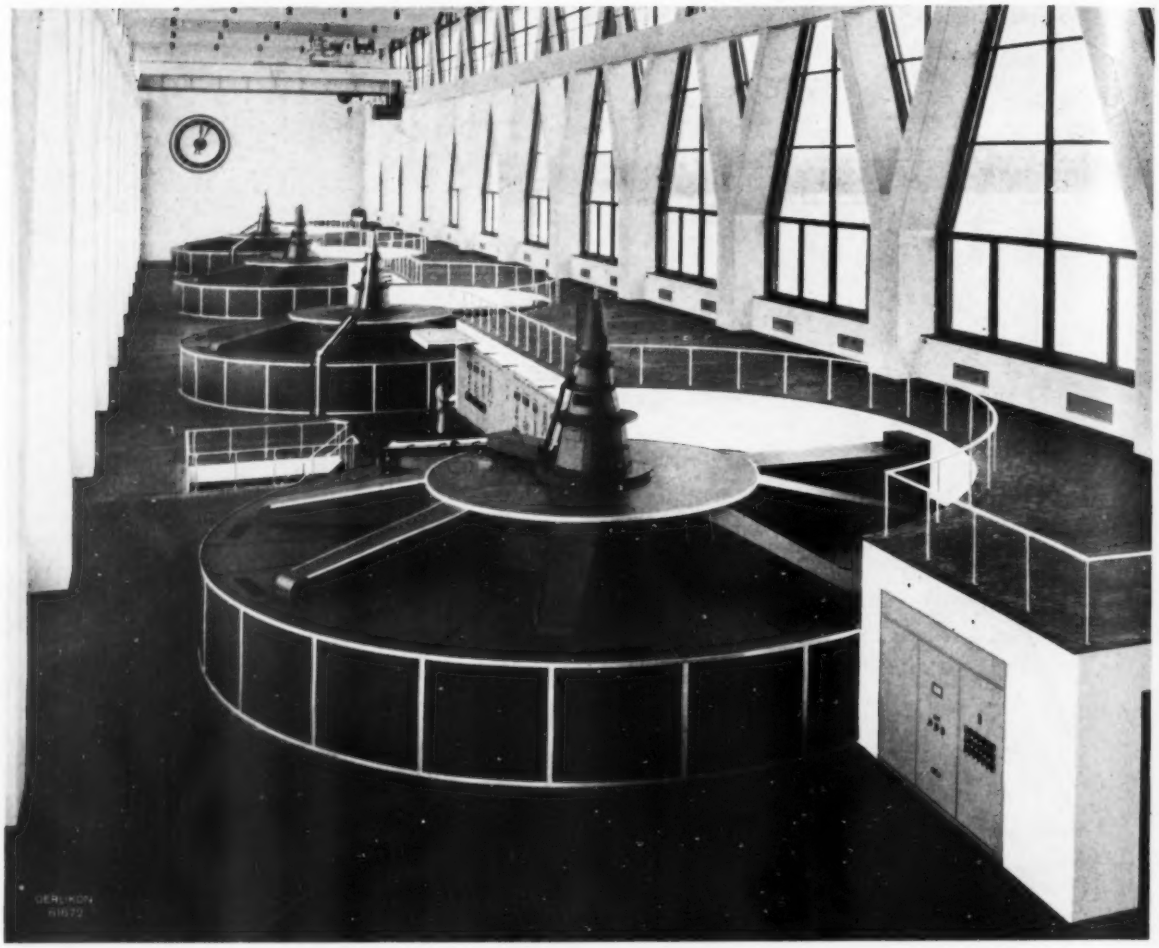


...are engaged on every continent in the development of major Hydro-Electric Power Plants



A new large low pressure power plant in operation

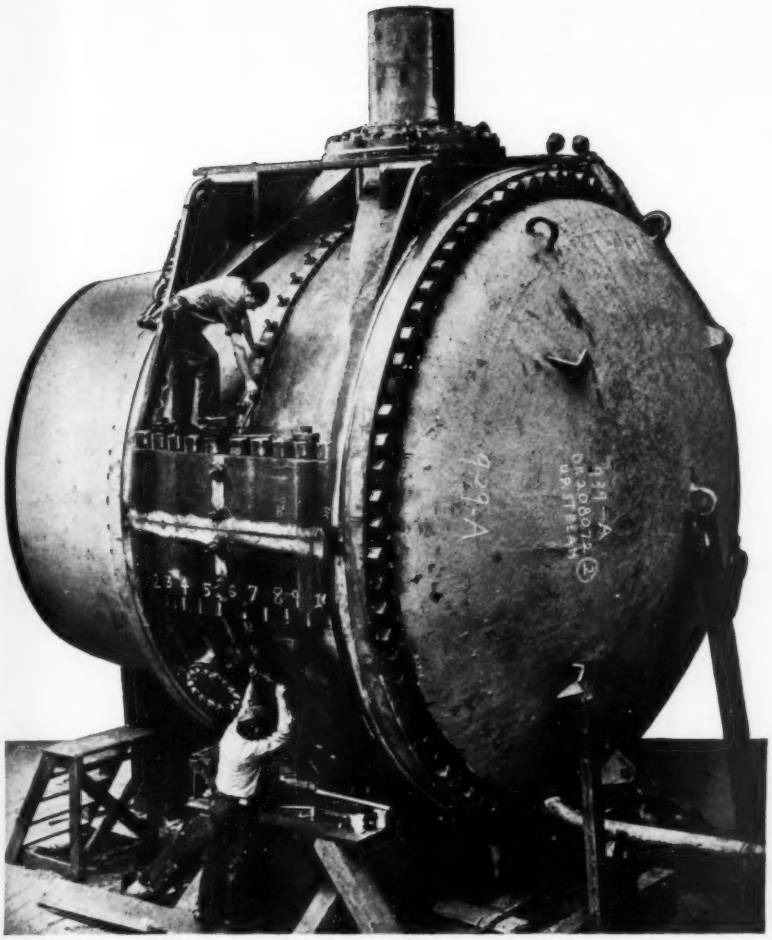
The new hydro-electric power plant at Birsfelden, near Basle, Switzerland, was inaugurated in November, 1955.
It is built in accordance with the most up-to-date rules and experience in civil, mechanical and electrical engineering. The above picture shows the interior of the engine house equipped with four vertical alternators, each of 26,000 kVA, 68 r.p.m., two of them Oerlikon made.

The Oerlikon alternators under erection

OERLIKON

Oerlikon Engineering Company
Zurich 50 Switzerland

Branch offices and representatives in Great Britain, Australia, Canada, India, South Africa, U.S.A.



This 16-Foot Butterfly Valve Illustrates the type of work which Newport News takes in stride. Newport News built 3 such valves, each weighing 446,000 lbs., for the Ross Power Plant, Skagit Project, Department of Light, City of Seattle, Washington. Designed for a water flow of 3,620 cu. ft. per sec., and a hydrostatic pressure of 290 psi., these valves were shop tested by Newport News at 450 psi. They are hydraulically operated with oil at 1,500 psi. pressure. Shop tests assure speedy, trouble-free assembly of Newport News built equipment, on the site.

The TEST of a TITAN

Here is one of the largest high head butterfly valves ever built, undergoing a shop test at Newport News. If you had an opportunity to follow this unit from start to finish, you would see *first hand* how Newport News produces massive equipment *economically*. For economy is a basic advantage that results from Newport News' high integration of skill and production facilities.

Large engineering and technical staffs, operating a plant comprising acres of brass, iron and steel foundries, five huge machine shops and other extensive fabricating facilities, have made Newport News one of the world's largest producers of hydraulic turbines, valves, gates, penstocks and other essential equipment... both standard and special in design.

Let us bid on your equipment. Write us today for your copy of *"Water Power Equipment."*

NEWPORT NEWS

SHIPBUILDING AND DRY DOCK COMPANY
Newport News, Virginia

MADE IN AUSTRIA

this is . . .

the beautiful baroque monastery of Melk on the Danube, housing a world-famous collection of mediaeva manuscripts.

Photo: FENZ

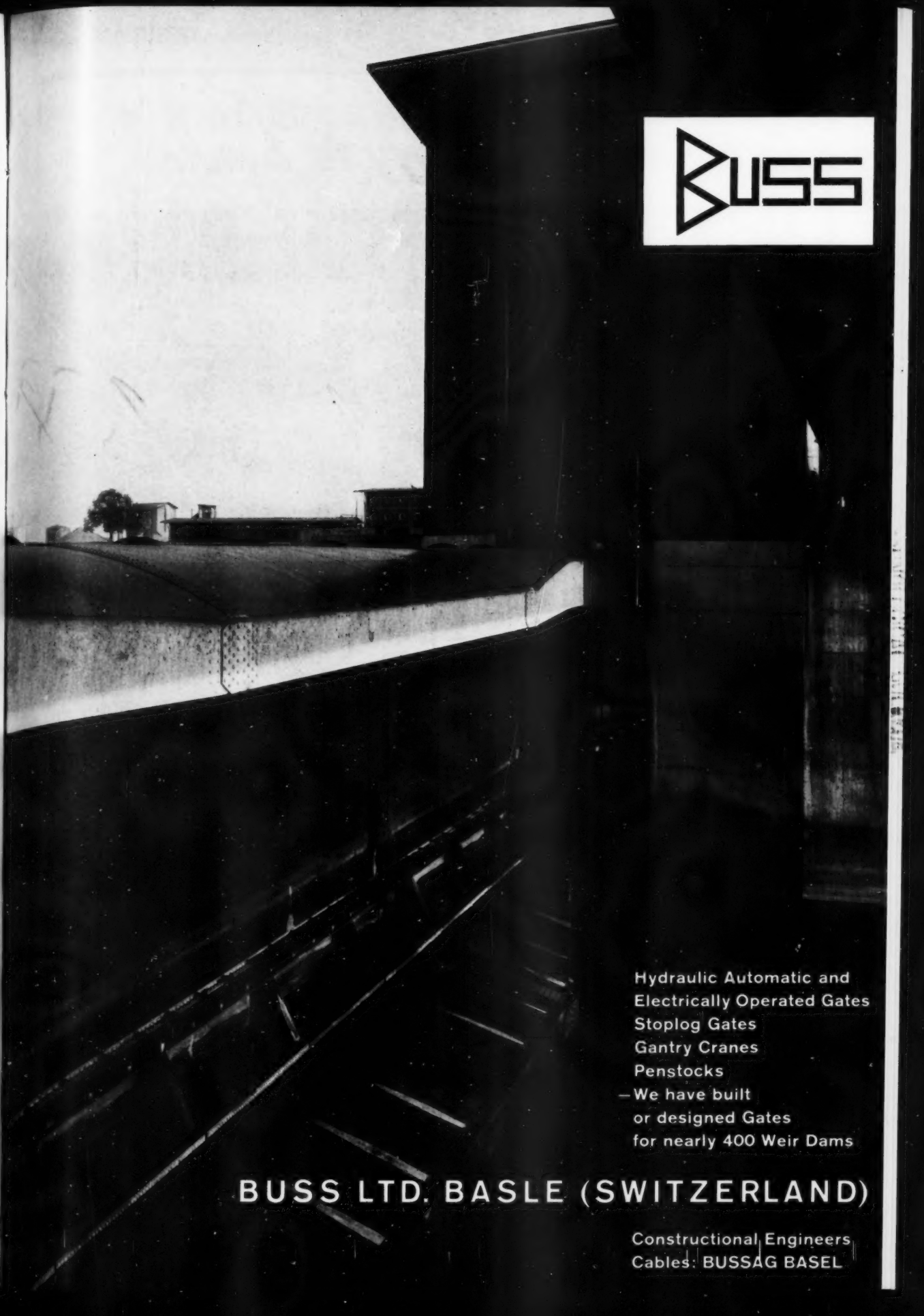
. . . and that is

the Jochenstein Power House on the same river Danube: an umbrella type rotor on the crane (35,000 kVA, 65.2 r.p.m., 92 poles).

Photo: KAISER

"ELIN" AKTIENGESELLSCHAFT FÜR ELEKTRISCHE INDUSTRIE

VIENNA AUSTRIA



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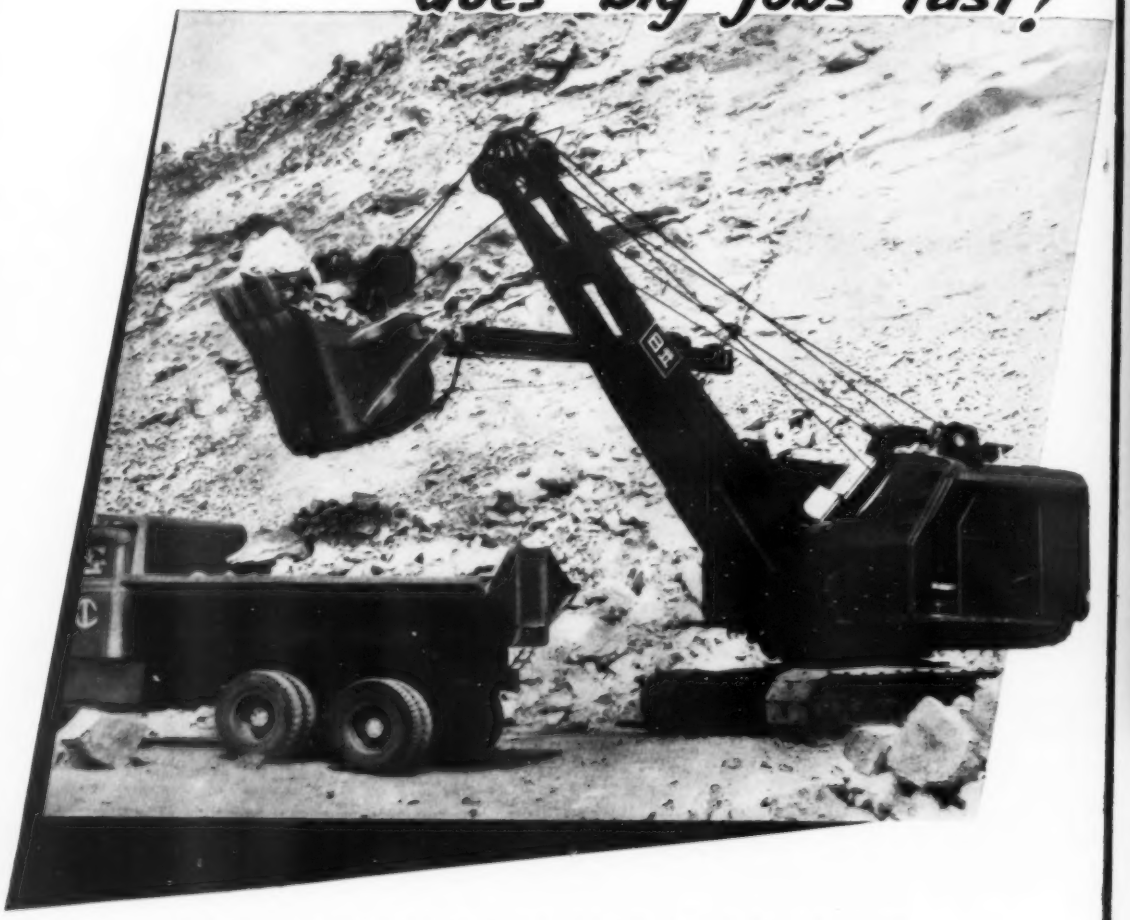
Precision built easy to handle

HITACHI CONVERTIBLE SHOVEL

does big jobs fast!

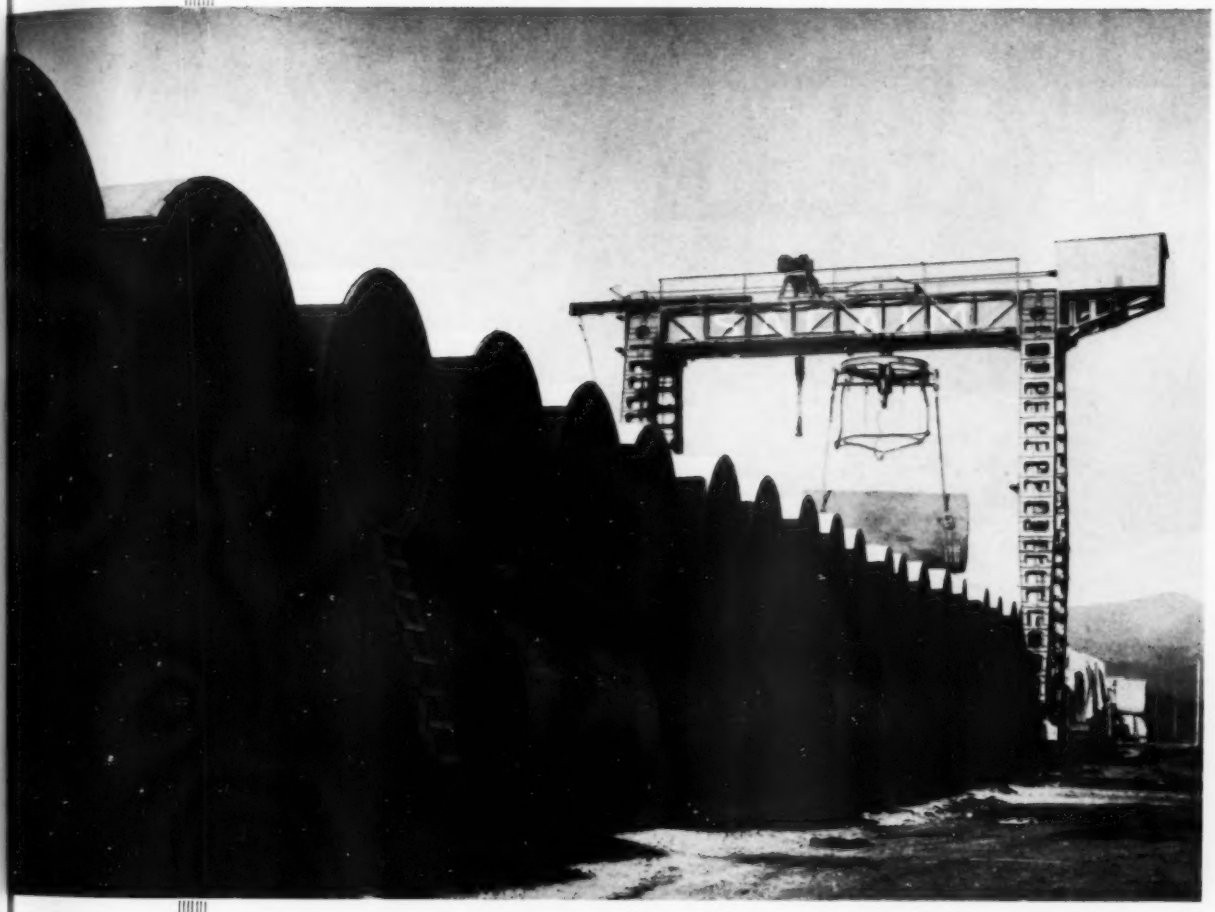


This convertible shovel is characterised by the use of shovel fronts of different types depending upon the purposes for which it is to be operated. The front may be changed to any of the following varieties considered most suitable for the given job: Shovel, dragline, clamshell, crawler type crane with a coal bucket; hook or drag shovel. A shovel is supplied with the machine as standard front equipment.

Hitachi, Ltd.

Tokyo Japan Cable Address: "HITACHY" TOKYO

Prestressed reinforced concrete penstocks of any diameter and pressure



Main penstock of prestressed reinforced concrete (diameter 6 ft. 7 ins., operating at 440 lb. per sq. in.) made for the Maè - Piave Hydro-Electric station of
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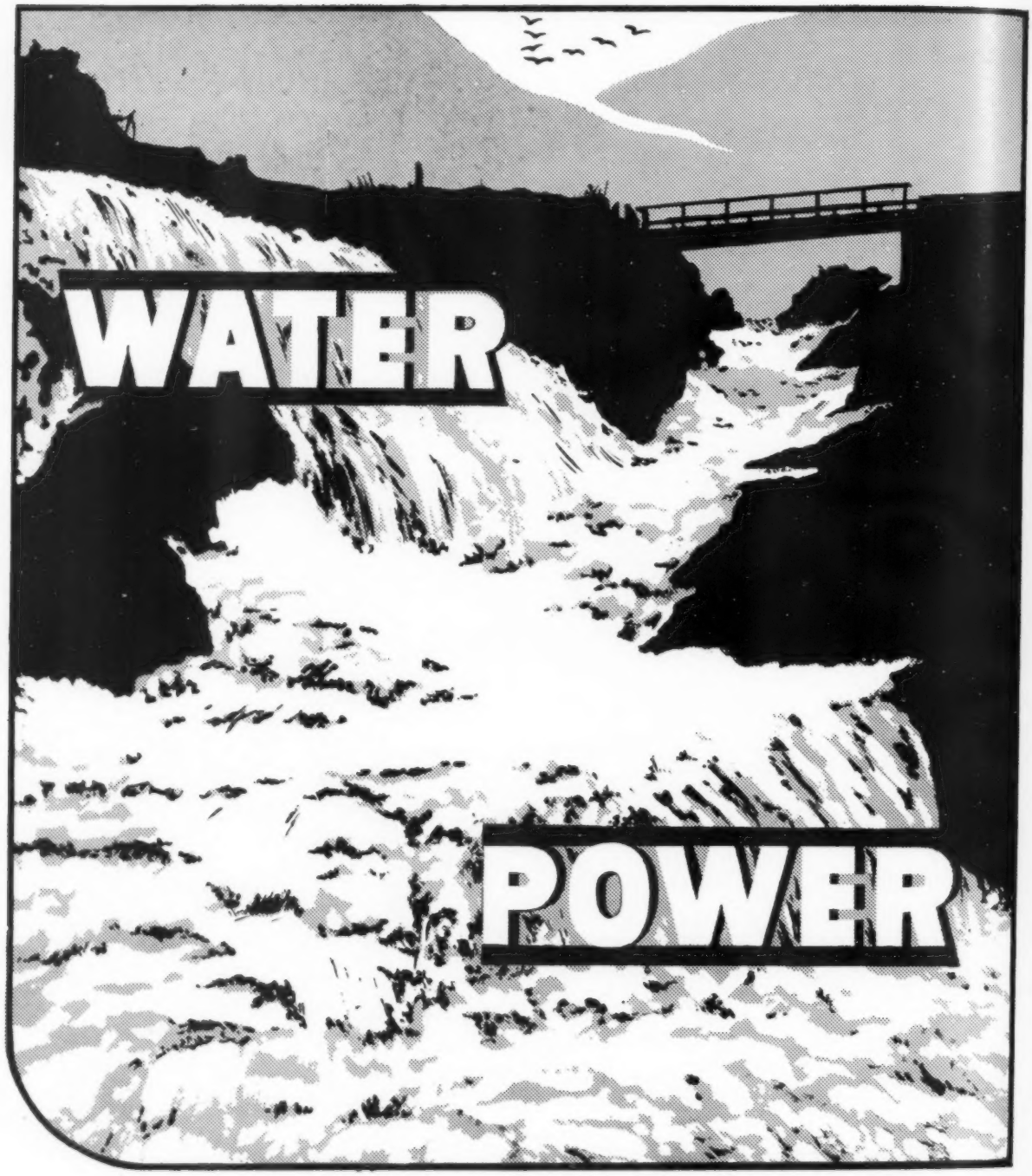

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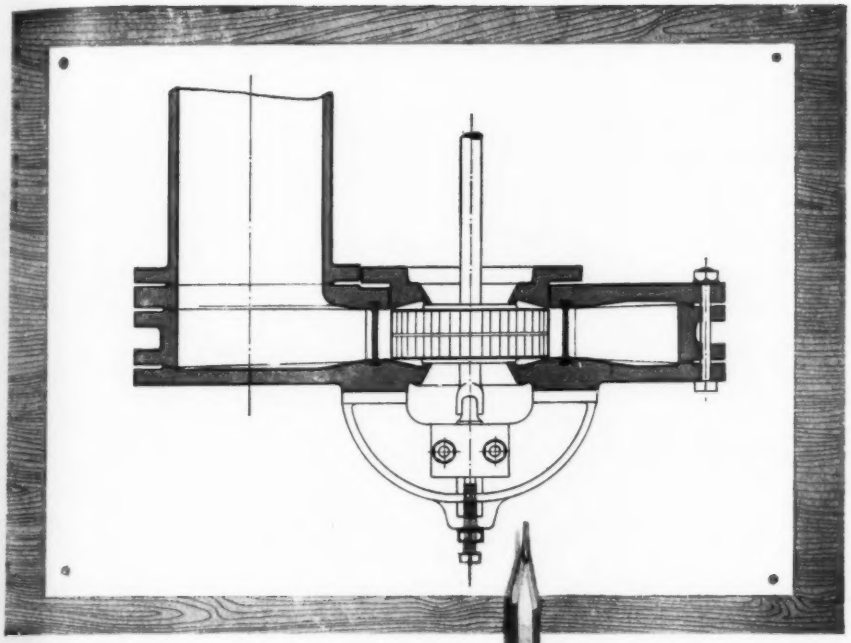
1856-1956



A dimensionless expression . . .

. . . of a century old determination to build better water turbines. This is a reproduction of one of the drawings of the first water turbine we built, in 1856 in our Works in Kendal. The drawings are beautifully executed and coloured, but have neither dimensions nor tolerances. Sizes were scaled from the drawing by the man on the job. The turbine, an advanced design in its day, is still at work driving machinery for Mr. John Robinson at Homescales, near Kendal. Using modern research and manufacturing techniques we build water turbines with outputs up to 10,000 B.H.P. which are shipped to all parts of the world. Our drawings are now dimensioned, but we admit no limit to our continued determination to serve the world well for another 100 years.

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G67

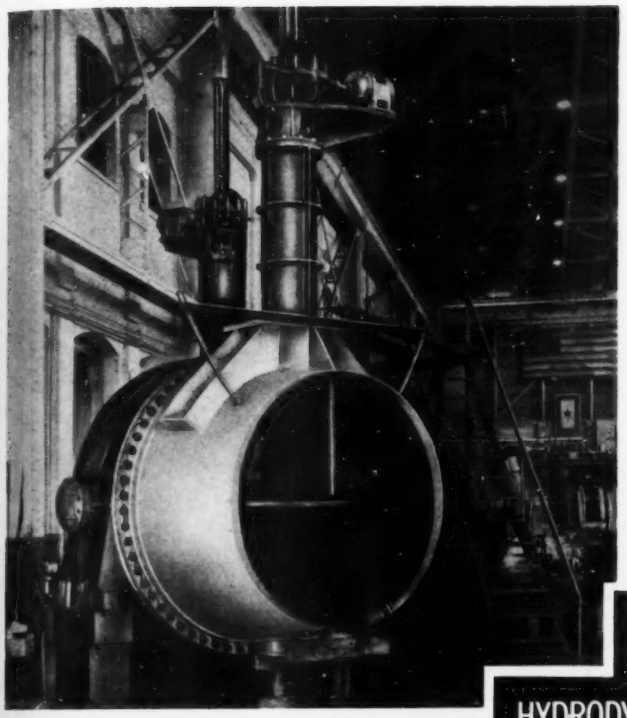
A 16-foot diameter tunnel leads from Ripogenus Dam to the surge tank, from which two penstocks feed the McKay Station turbines. Each turbine has a plate steel spiral case, shop-welded in two halves with riveted butt strap connections. SMS accessory equipment is installed at the dam and in the station. Consulting engineers: Stone and Webster Engineering Corp

SMS TURBINES POWER RIPOGENUS EXPANSION

On the upper Penobscot River, Ripogenus Dam had been a storage reservoir for Great Northern Paper Company's downstream power plants since 1916. When studies made in 1950 indicated more power was needed, McKay Station was built. A 4,000-foot, rock-lined tunnel, leading from a new intake in the dam face to the power house below, created a net effective head of 175 feet. Two vertical SMS-Francis turbines, rated at 16,590 hp, were installed, and provision made for the ultimate addition of another unit.

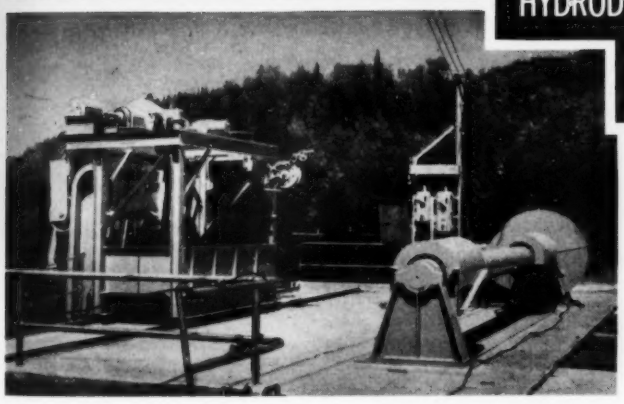
SMS hydraulic equipment was chosen for the entire project. The 18 x 20-foot fixed wheel turbine intake gate is operated by a twin-drum, motor-driven chain hoist. A special log-grapple type trash rack rake keeps the intake free of pulp wood and other debris. Two 108-inch SMS-Dow valves provide shut-off at the turbine inlets.

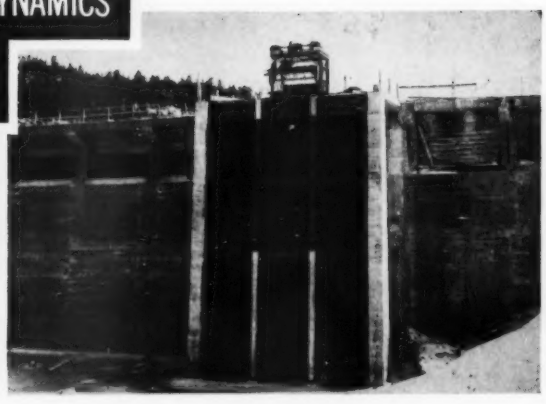
This Ripogenus hydroelectric expansion typifies S. Morgan Smith's ability to satisfy the complete needs of any project. Over 75 years of world-wide experience in design and manufacture of hydraulic turbines and accessories assures you of equipment that will meet the highest standards. For full information, write S. Morgan Smith Company, York, Pennsylvania.



Motor-operated Dow valves, installed at the inlet of each spiral case, provide tight shut-off. Note the streamlined valve disc and housing around the operating link connection to the disc.

HYDRODYNAMICS





SMS intake gate is installed at the left end of the dam. The 10-foot trash rack rake and self-contained trash car are shown (right) in lowering position above the center rack. Lower left photo shows rear view of the hoist support and trash car, with the 60,000 lb. intake gate hoist in the foreground.

SMS

S. MORGAN SMITH

AFFILIATE: S. MORGAN SMITH, CANADA, LIMITED, TORONTO

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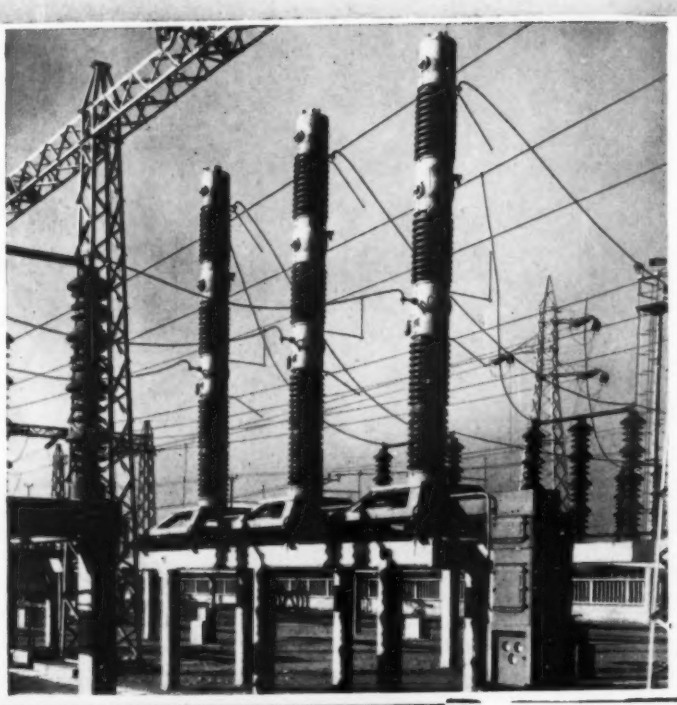
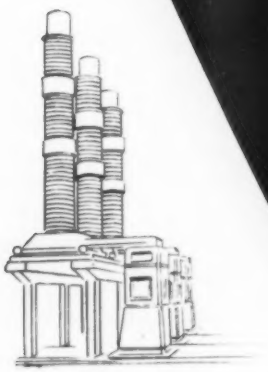


Type PO/350-N circuit breaker suitable for 150 kV, having 2200 MVA breaking capacity, installed at the Treviglio substation of the Italian State Railways, along the railway line from Milan to Venice



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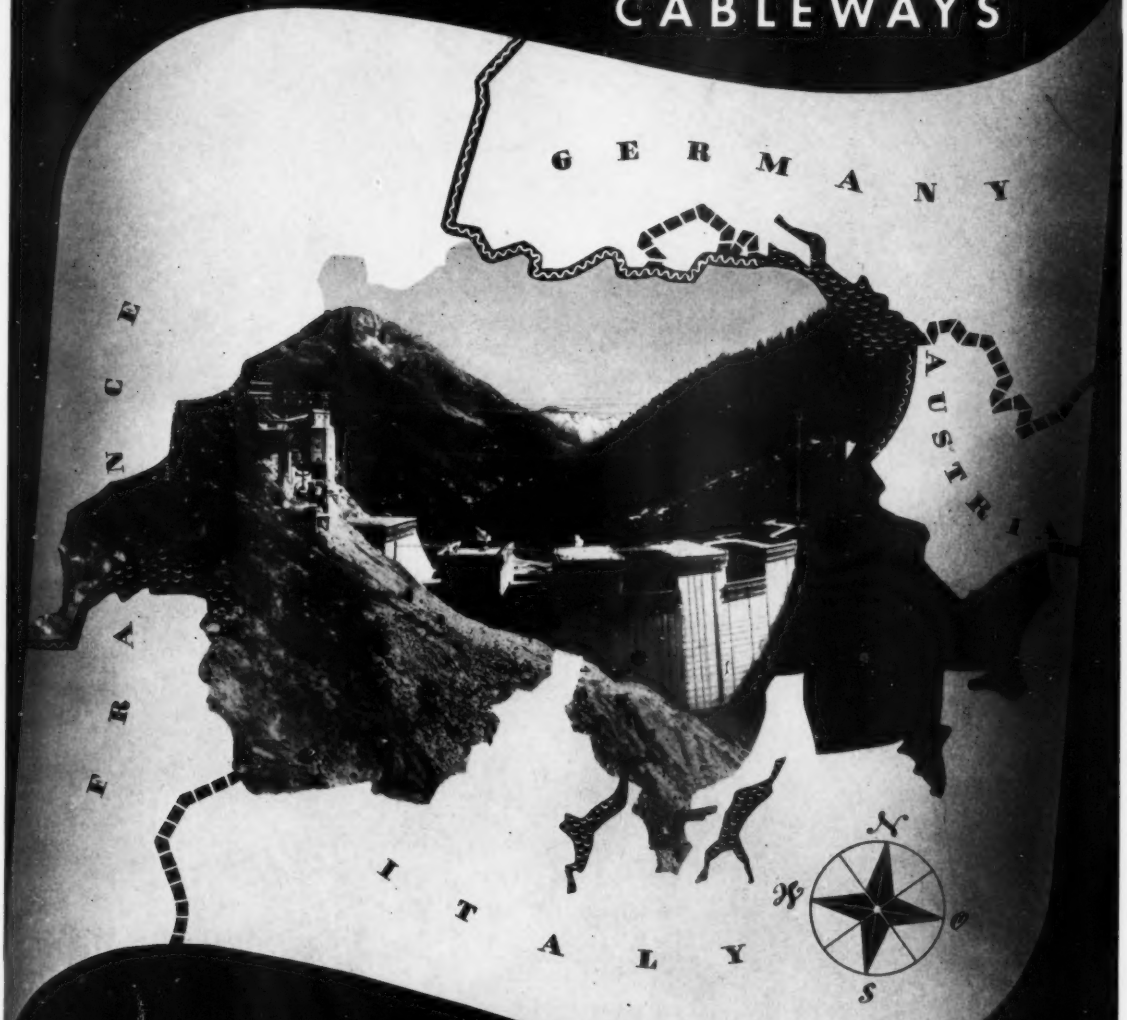

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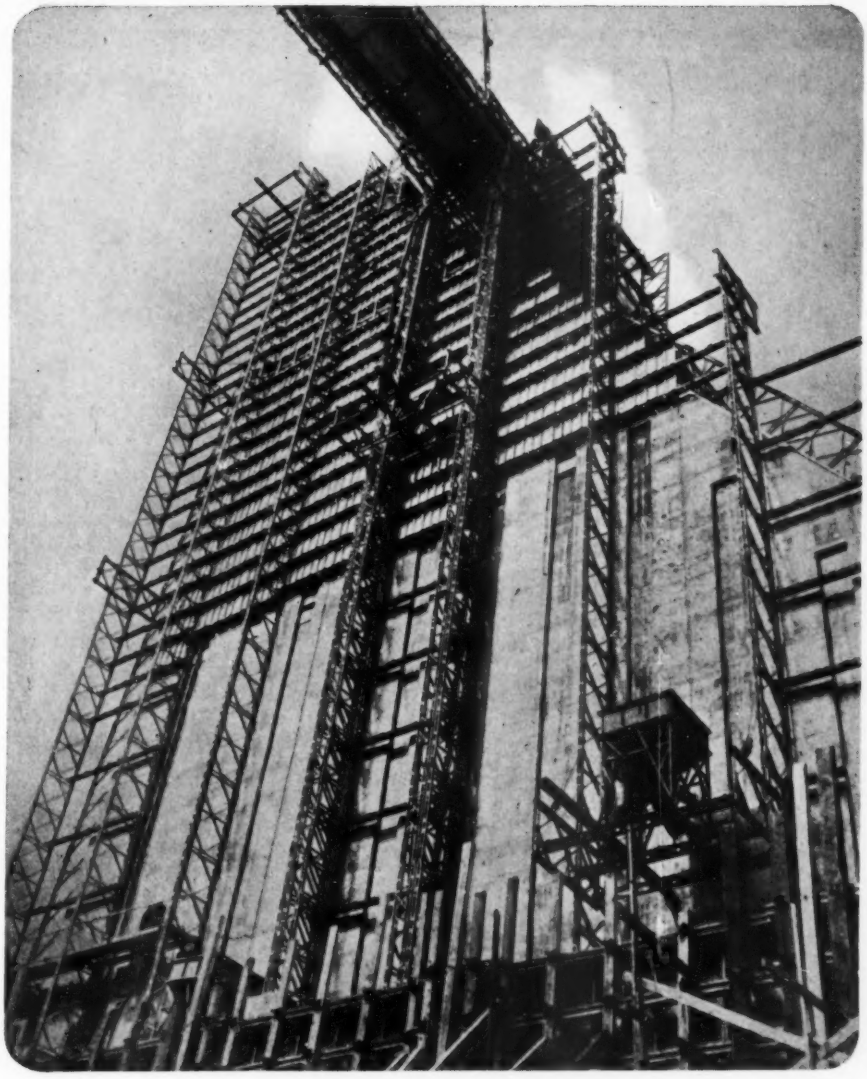

Photograph by courtesy of the Ontario Hydro Electric Commission

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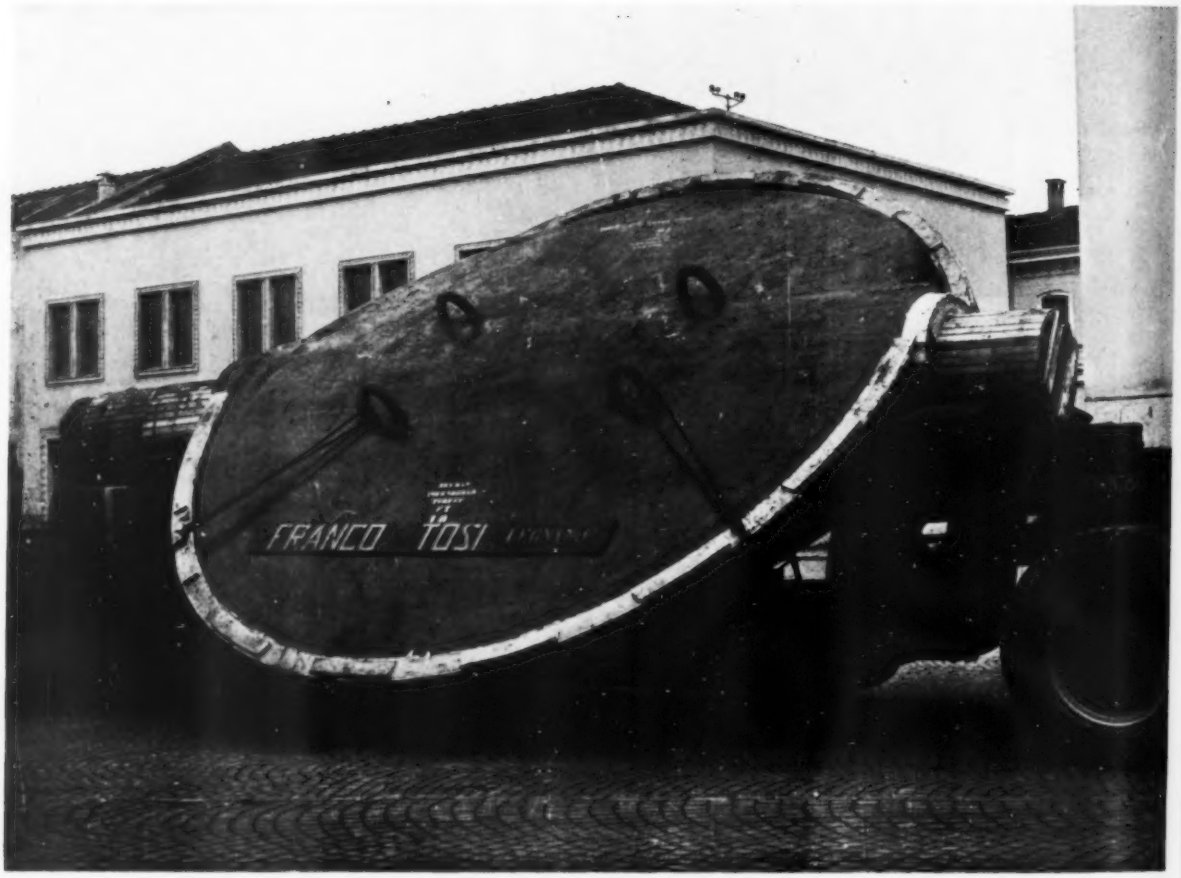
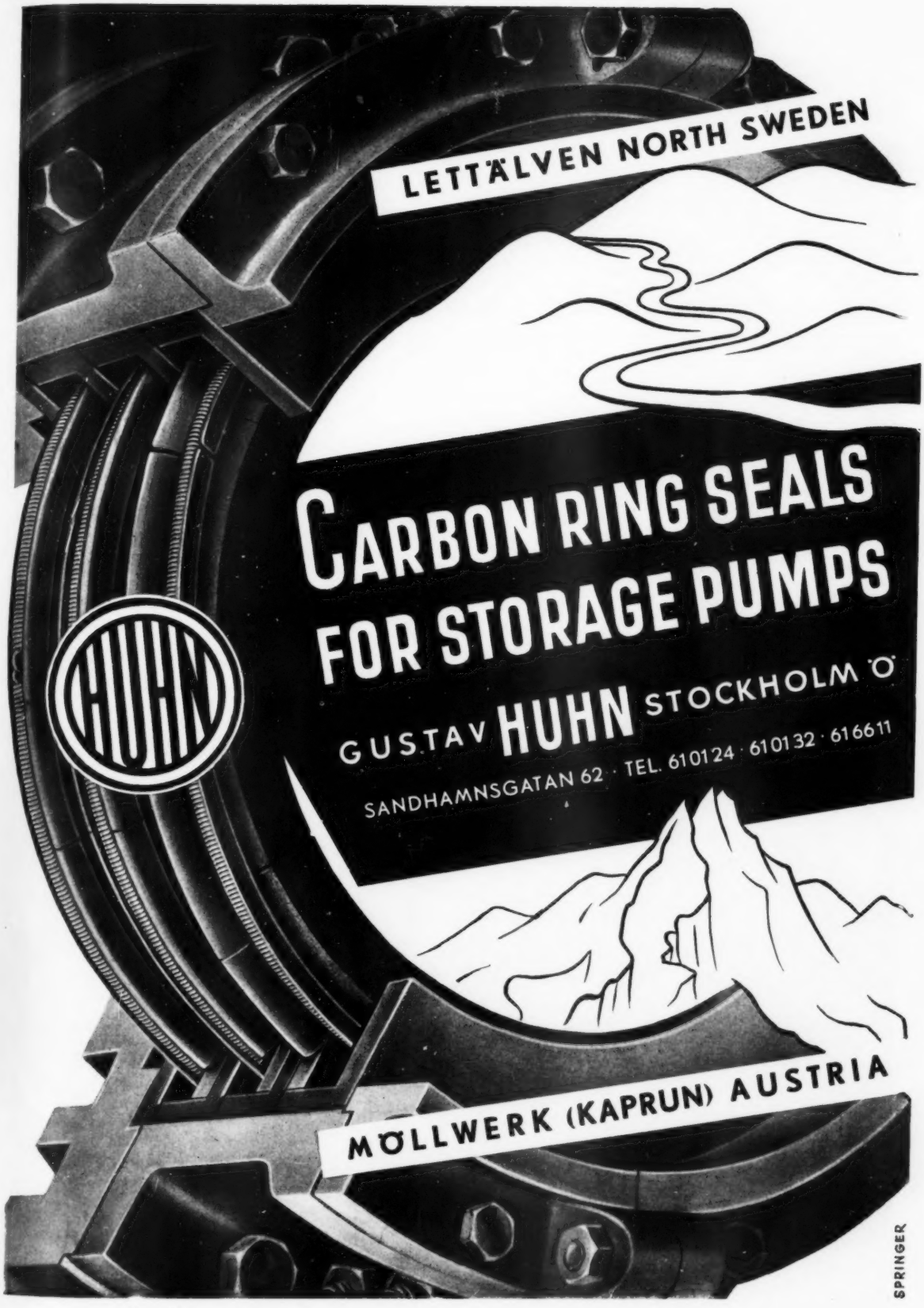


SEYHAN WATER PROJECT (TURKEY)

Butterfly Valve Leaf, 5,020m. Diameter—Weight 50 Tons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n. réf. / / /

A rappeler dans votre réponse

LABORATOIRE DAUPHINOIS D HYDRAULIQUE

GRENOBLE, le January 15th 1956.

OBJET :

V. réf. :

Dear Sir,

The Laboratoire Dauphinois d'Hydraulique, which until recently was a branch of the Etablissements NEYRPIC, has for some time been developing and extending its activities. This trend led, in March 1955, to the formation of a new company specialising in hydraulic studies. Its object was to take over progressively all the functions of the Laboratoire Dauphinois d'Hydraulique. We are now able to tell you that this process was finally completed on 1st January 1956.

SOGREAH is a company of Consulting Engineers, specialising in hydraulic techniques in particular and in fluid mechanics in general, with every facility for supporting its theoretical work with laboratory tests.

Since the personnel of the Laboratoire Dauphinois d'Hydraulique of the Etablissements NEYRPIC has been transferred almost in its entirety to our company, the same staff will be at your disposal to deal with any problem that you may require solved.

We shall continue to do all in our power to merit your confidence.

Yours faithfully,

Le Directeur Général Adjoint, — *Le Président-Directeur Général,*

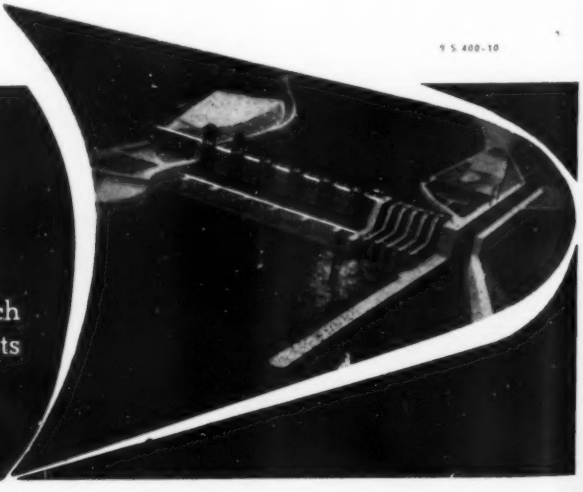
G. Sauvage de St Marc — Pierre Danel

Gaston SAUVAGE de SAINT MARC — Pierre DANEL.

9 S 400-10

GRENOBLE
Avenue Léon-Blum

PARIS (VIII^e^)
155, Bd Haussmann



Theoretical and experimental research and studies — Scale model tests

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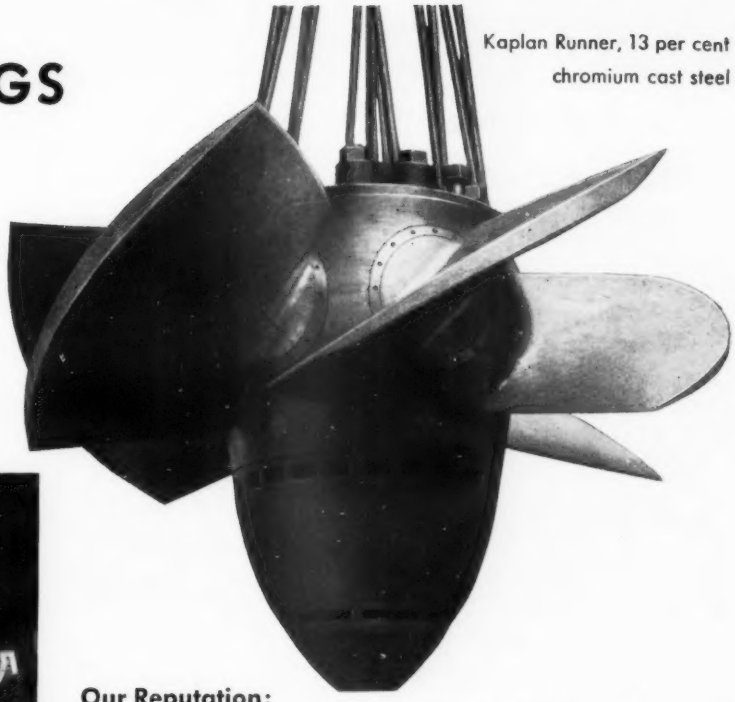
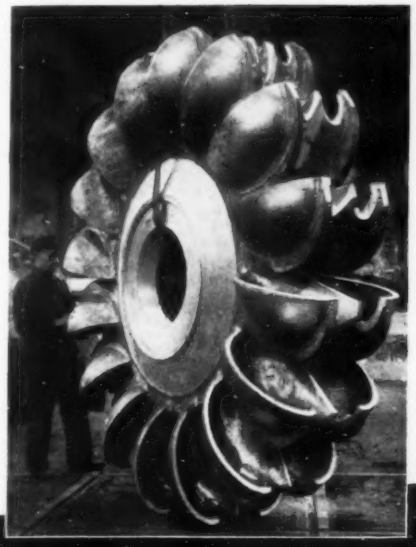


Kaplan Runner, 13 per cent chromium cast steel

Impulse Runner, Cast in one piece



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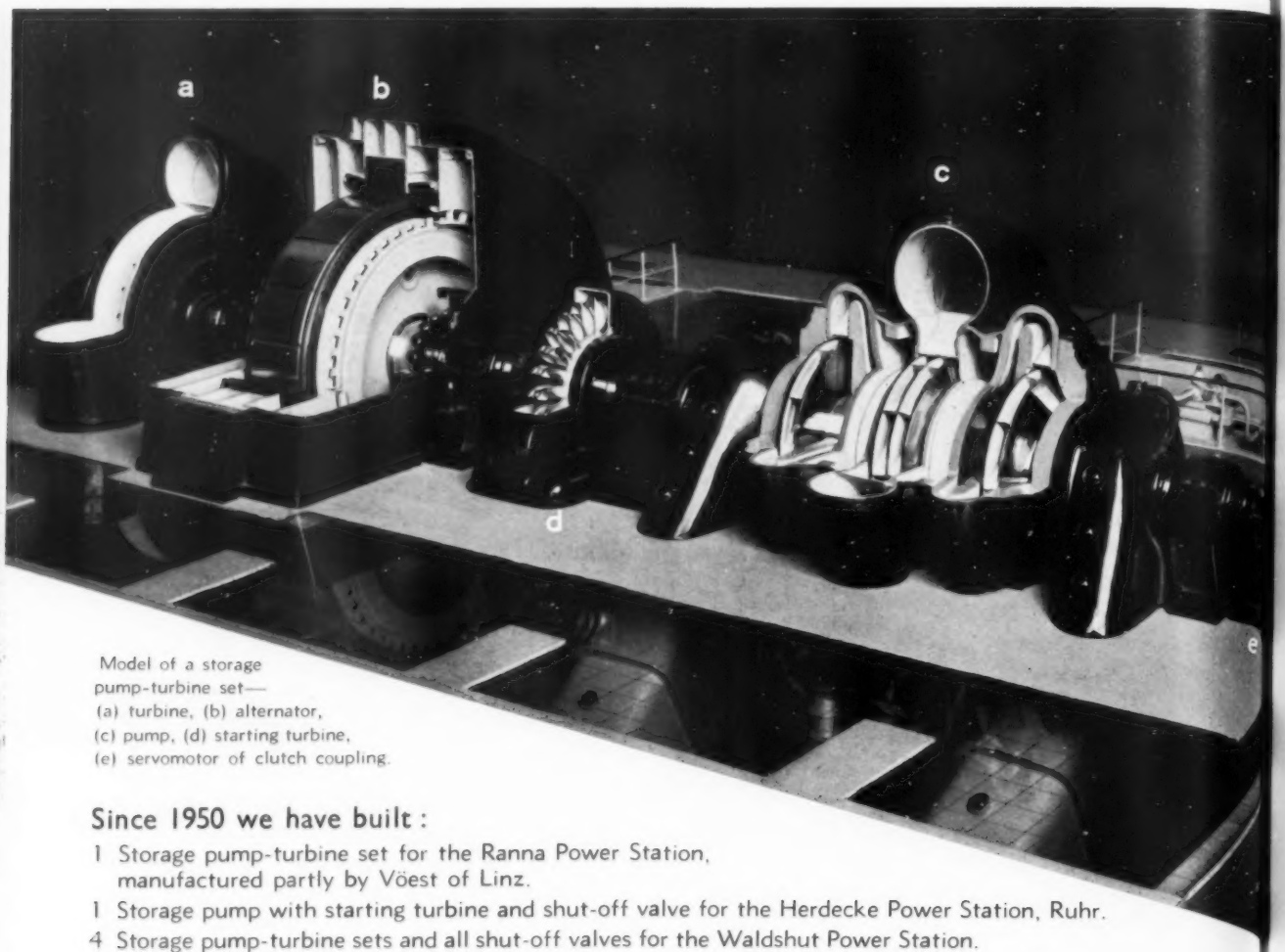

Model of a storage pump-turbine set—
(a) turbine, (b) alternator,
(c) pump, (d) starting turbine,
(e) servomotor of clutch coupling.

Since 1950 we have built :

1 Storage pump-turbine set for the Ranna Power Station, manufactured partly by Vöest of Linz.
1 Storage pump with starting turbine and shut-off valve for the Herdecke Power Station, Ruhr.
4 Storage pump-turbine sets and all shut-off valves for the Waldshut Power Station.
1 Storage pump-turbine set and shut-off valves for the Gobantes Power Station (Spain).
1 Storage pump for the Rodund Power Station, ILL (Austria), in conjunction with Voith of St. Pölten.
2 Storage pump-turbine sets with all shut-off valves for the Reisach Power Station (see illustration).
1 Storage pump-turbine set with shut-off valves for the Brattingfoss Power Station (Norway).

We have on order :

2 Storage pumps and shut-off valves for the Ottenstein Power Station (Austria), manufactured to a large extent by Vöest of Linz. Pump input 12,500 H.P. each.
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We have extensive resources of modern laboratories, testing equipment and up-to-date manufacturing facilities. Our staff possesses wide experience and high technical skill in the design, construction and erection of most progressive hydraulic equipment that is efficient and dependable in operation. Our experts are at your service, without obligation, to advise and assist you with technical information and preliminary estimates.

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Highland water power

This is Errochty power station on the shore of Loch Tummel. It is the largest generating station in the Tummel-Gary Scheme of the North of Scotland Hydro-Electric Board, and houses three 25 MW vertical-shaft hydro-alternators built and installed by G.E.C. Auxiliary motors and most of the control gear in the station were also supplied by G.E.C.

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AFRICA.	Owen Falls - Uganda
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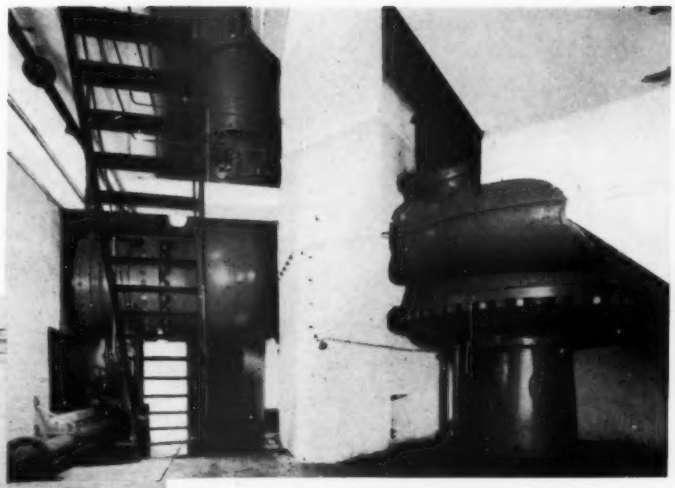
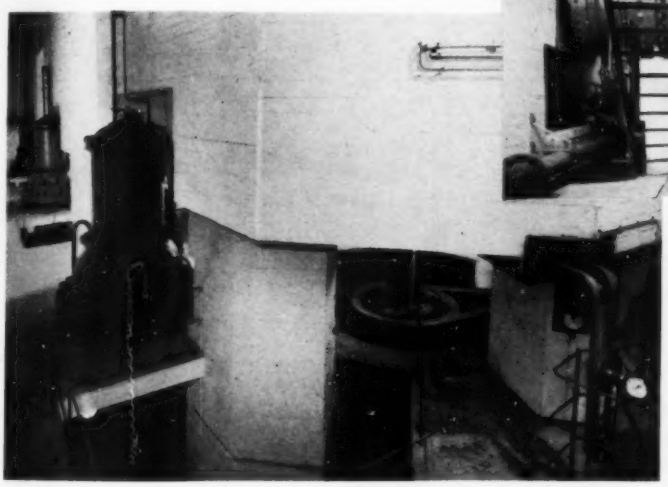


View of one of the VINSTRA turbines and main sluice valve



Governor platform showing regulator ring of one of the turbines and parts of the main sluice valves.

In the near future we are passing 6,000,000 h.p. total output for turbine-runners delivered and on order.

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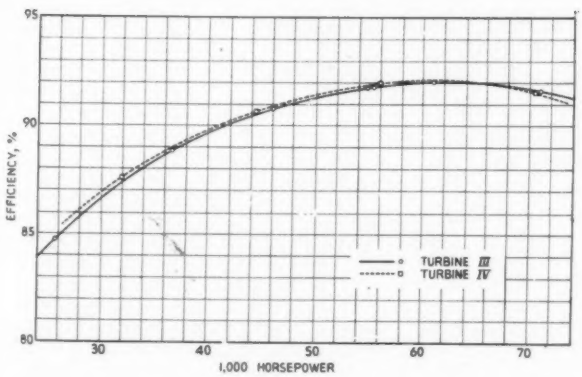

Efficiencies actually obtained on Vinstra turbines III and IV on official test, June 23-24, 1953

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For power stations of all kinds (water, steam, and Diesel power stations) we supply generators, transformers, complete switchgear and control rooms, regulating and protecting equipment, and carrier telephone links. In addition, for steam power stations, we build Velox boilers, steam turbine sets, and condensing plants.

One of the three 49500-kVA, 100-r.p.m., 11-kV, 50-c/s vertical-shaft generators Brown Boveri are building for the Egyptian hydro-electric power station Aswan on the Nile. — One of two 30000-kVA, 514-r.p.m., 60-c/s generators for the Hidrandina S.A., Lima (Peru), is visible on the right below.

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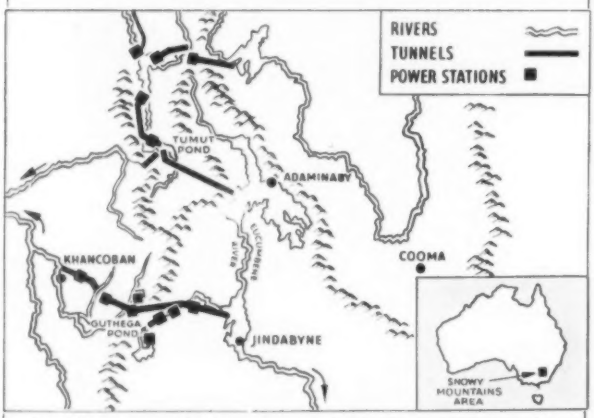
1755

ATLAS COPCO EQUIPMENT IN ACTION AS GIANT SNOWY MOUNTAINS SCHEME GETS UNDER WAY

Guthega power house near completion. It is providing the first water power from the Snowy Mountains scheme.



The scheme is one of the biggest power and irrigation projects ever undertaken in the world.

25 YEARS TO COMPLETE

The Australian Alps, south-west of Canberra, are the location of one of the biggest power and irrigation projects ever undertaken in the world. It is the Snowy Mountains scheme, expected to take 25 years and £A 422,000,000 to complete.

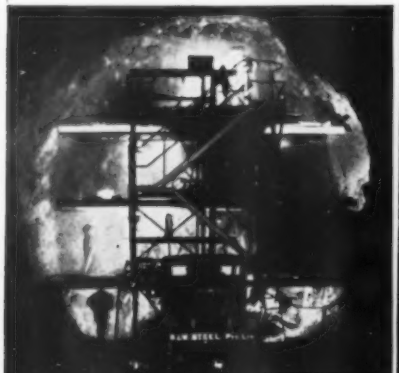
On the eastern slopes of the highest mountain in this 100-mile range, the Snowy River rises and then flows down to the south-east coast. Eventually this river will flow *westwards* to provide 2 million acre feet of water a year for irrigation and power stations with a total generating capacity of 3 million kilowatts.

85 MILES OF TUNNELLING

The Snowy Mountains scheme is engineering on a massive scale. It involves the construction of 7 major dams, 10 smaller ones, 85 miles of tunnels, 17 power stations (most of them underground), 400 miles of aqueducts, numerous shafts ranging up to 1,100 feet in depth, and hundreds of miles of mountain roads and access tracks. From the beginning, Atlas Copco rock drills, Atlas Copco air compressors and Sandvik Coromant drill steels are being widely used on many of these operations.

ATLAS COPCO PREPARE THE WAY

The first major stage of the scheme, the Guthega hydro-electric project consisting of a 100-ft. dam, a 3½-mile tunnel and a power station, has already been completed and is providing the first water power from the scheme. Atlas Copco rock drills fitted with Sandvik Coromant drill steels were chosen for the tunnels and all other rock excavations. This drilling unit was also at work building miles of mountain roads to prepare the way for the contractors, the Selmer Engineering Company of Norway.



Tunnelling at Adaminaby Dam diversion tunnel from jumbos, mobile drilling platforms pioneered by Atlas Copco.

Intake structure for the 3½-mile Guthega tunnel driven by Atlas Copco drills fitted with Sandvik Coromant steels.

Bottom of a shaft drilled by Atlas Copco drills and Sandvik Coromant steels on the Adaminaby diversion tunnel.

Battery of ten Atlas Copco AR 4E compressors installed at the junction shaft of the 14-mile Eucumbene-Tumut tunnel.

Atlas Copco drills fitted with Sandvik Coromant drill steels in action in the Guthega tunnel, the first major stage of the scheme.

BATTERY OF TEN ATLAS COPCO COMPRESSORS SUPPLY POWER FOR 14-MILE TUNNEL

Atlas Copco equipment is also in action on the second stage of the Snowy Mountains scheme. The main contractors are the American group Kaiser-Walsh-Perini-Raymond. On the Eucumbene-Tumut project Atlas Copco rock drills and Sandvik Coromant drill steels are widely used for various drilling operations, for example drilling a 4,000 feet access tunnel into the main tunnel. Here the rock drills are fed by Atlas Copco portable compressors. And at the main tunnel a battery of ten Atlas Copco AR4E compressors is the main power source for the drilling operations. A number of Atlas Copco AR3 compressors are also used by the Australian contractors, Allied Construction Pty. Ltd., on the diversion tunnel to Adaminaby Dam.

Over the past ten years, Atlas Copco light rock drills and Sandvik Coromant drill steels have become the world's most widely-used drilling combination. Both were developed together. Both are *working together;* turning projects like the Snowy Mountains scheme into reality all over the world.

From the start, Atlas Copco drilling equipment has been widely used on the Snowy Mountains scheme.

The services of the Project Department of Atlas Copco, whose job is to draw up drilling patterns and to advise on tunnelling and mining techniques, are at the disposal of contractors everywhere without obligation.

Drilling on the Guthega power station site with an Atlas Copco drill and Sandvik Coromant drill steels.

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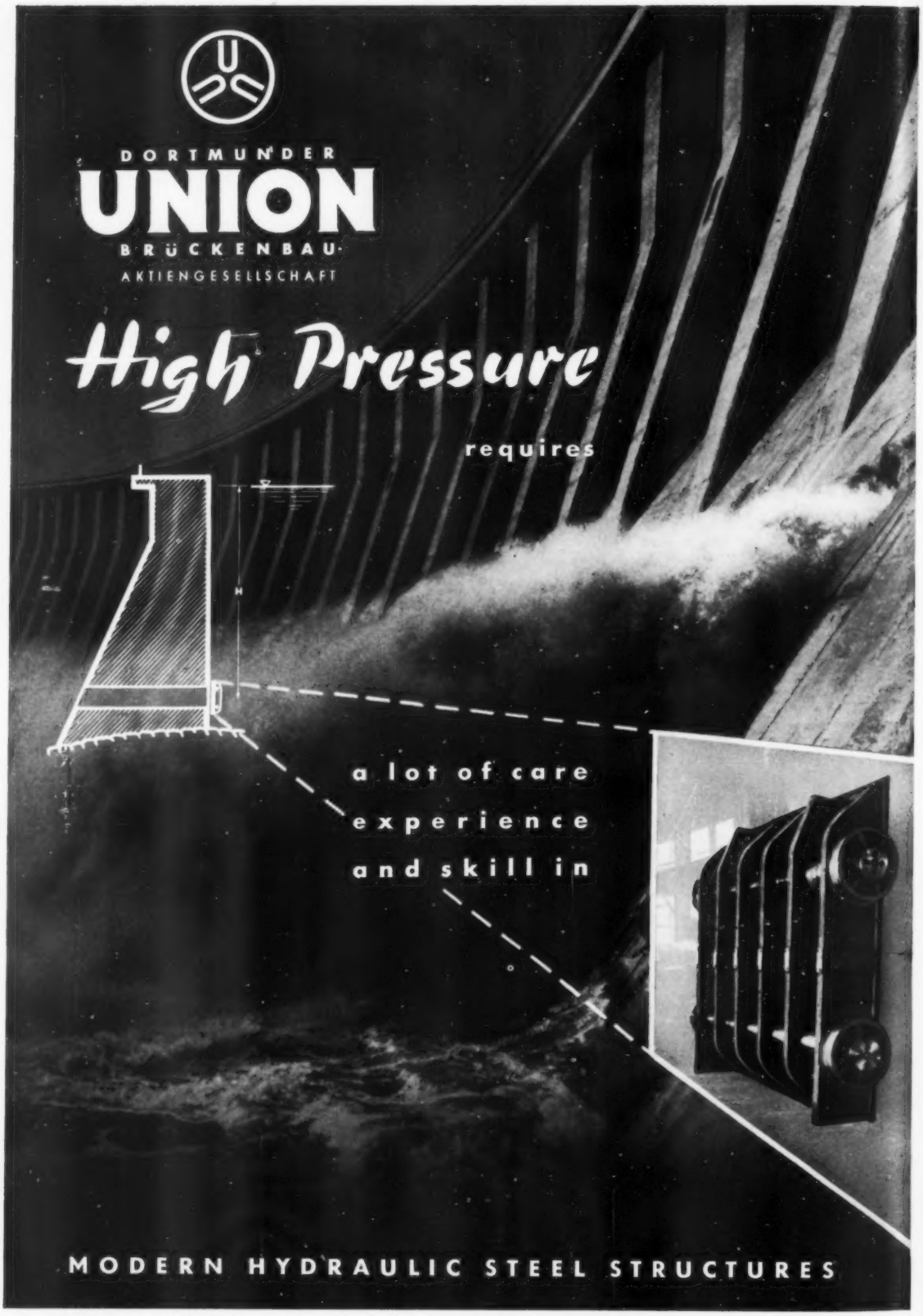

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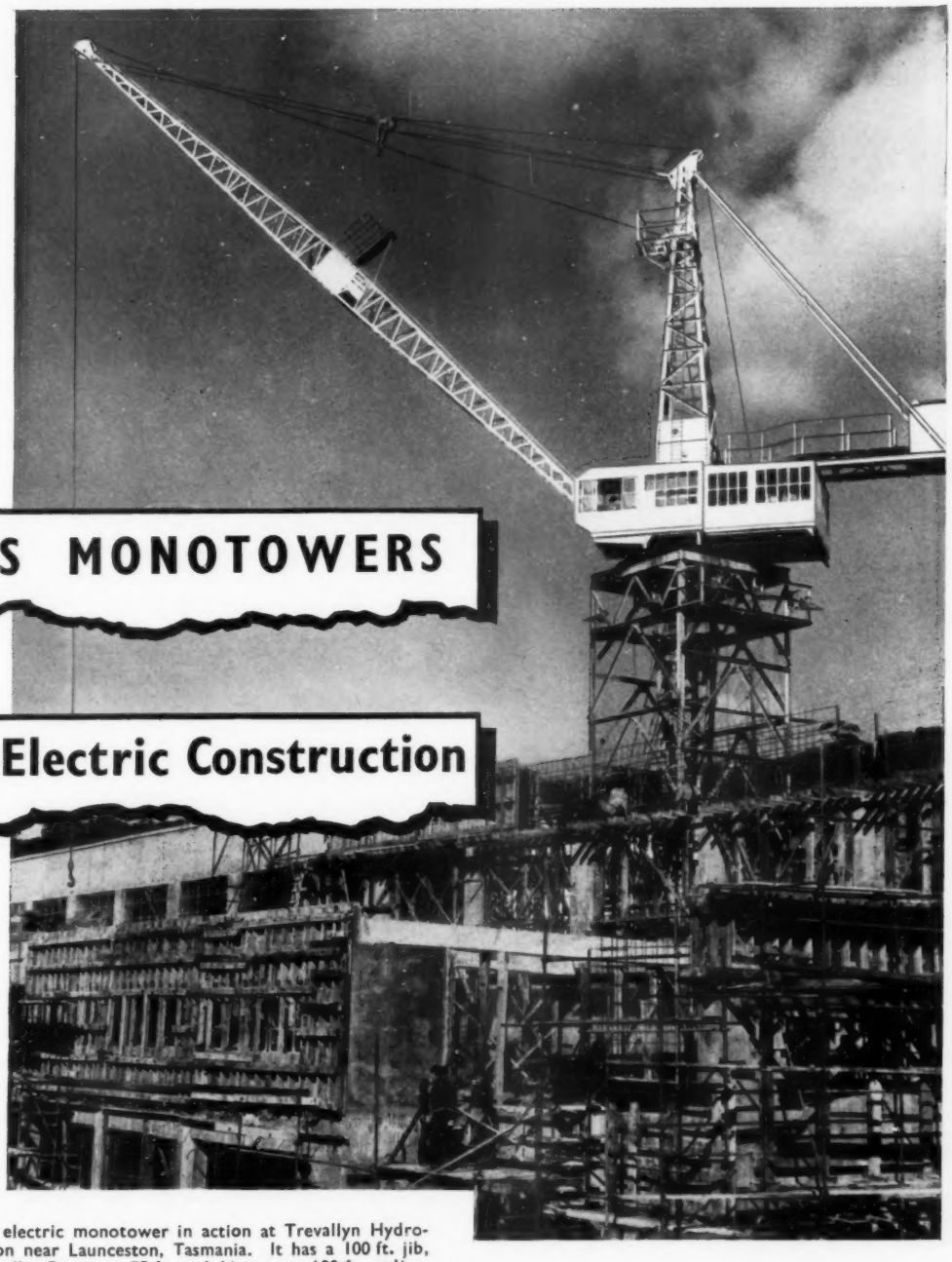

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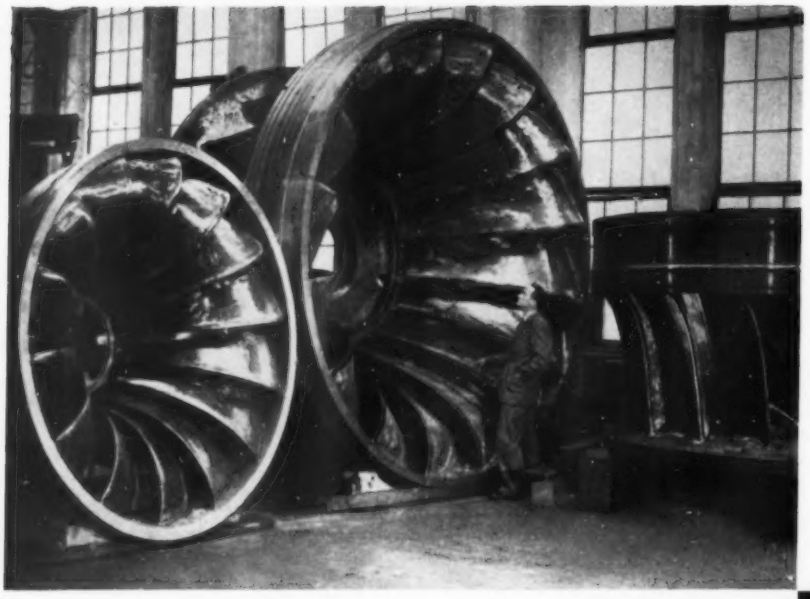

Runners for Francis turbines in our works. *Left:* Head 112 ft., output 21,500 h.p., runner diam 9 ft. 6 in., speed 150 r.p.m. (Laforsen Power Station). *Centre:* Head 160 ft., output 47,000 h.p., runner diam 10 ft. 10 in., speed 150 r.p.m. (Storfinnforsen Power Station).

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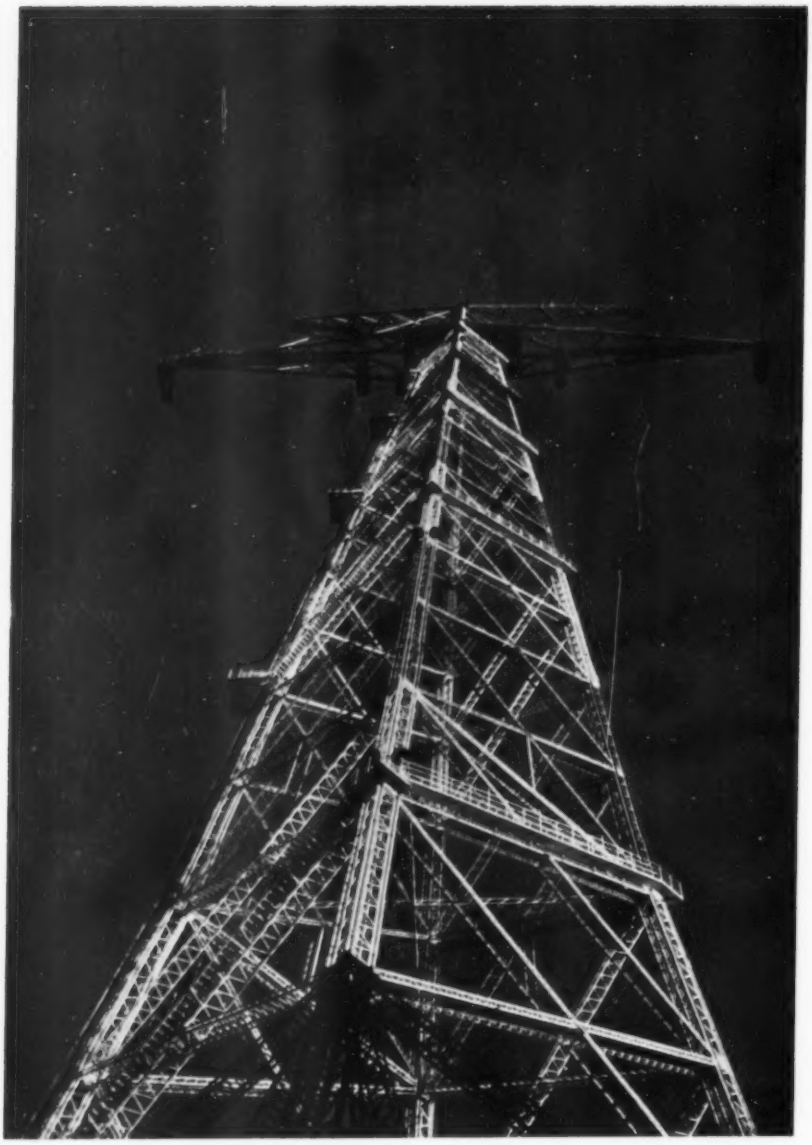

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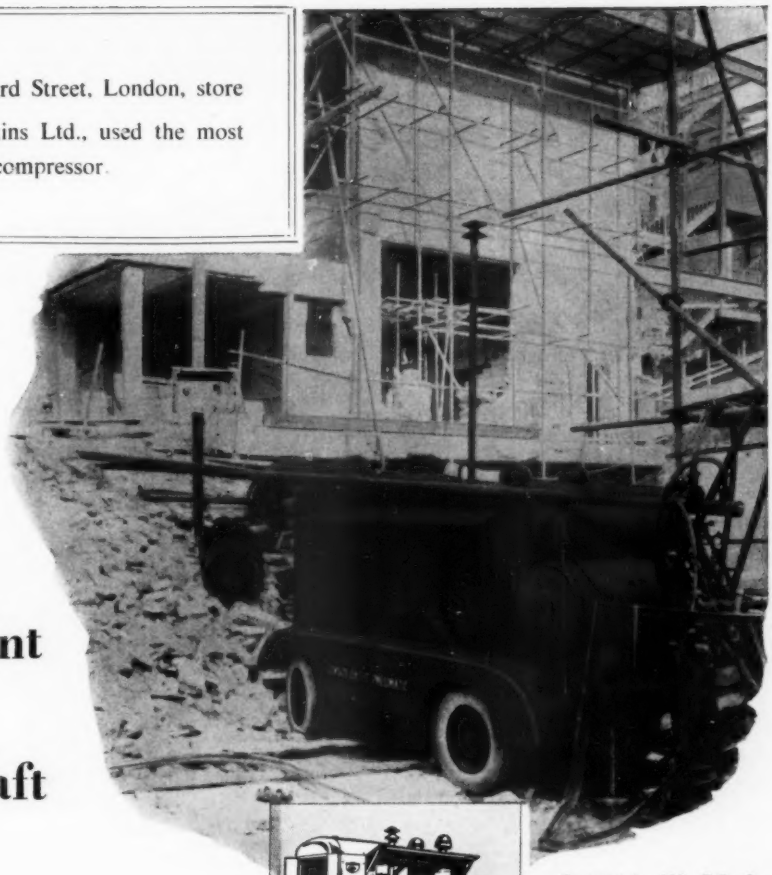

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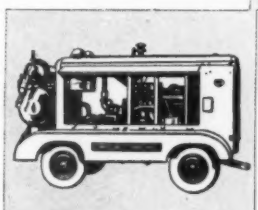

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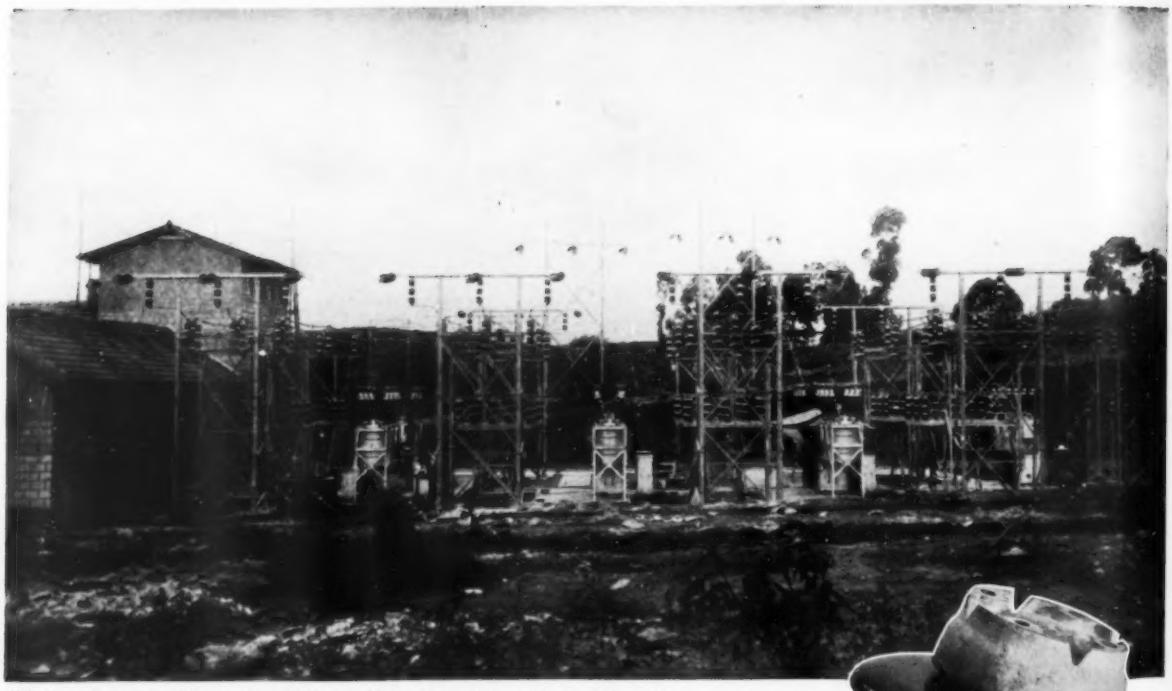

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The substation at Kothamangalam, Travancore, India, one of the 66kV substations on the Pallivasal project equipped with S.P.P. Post insulators type P.642.

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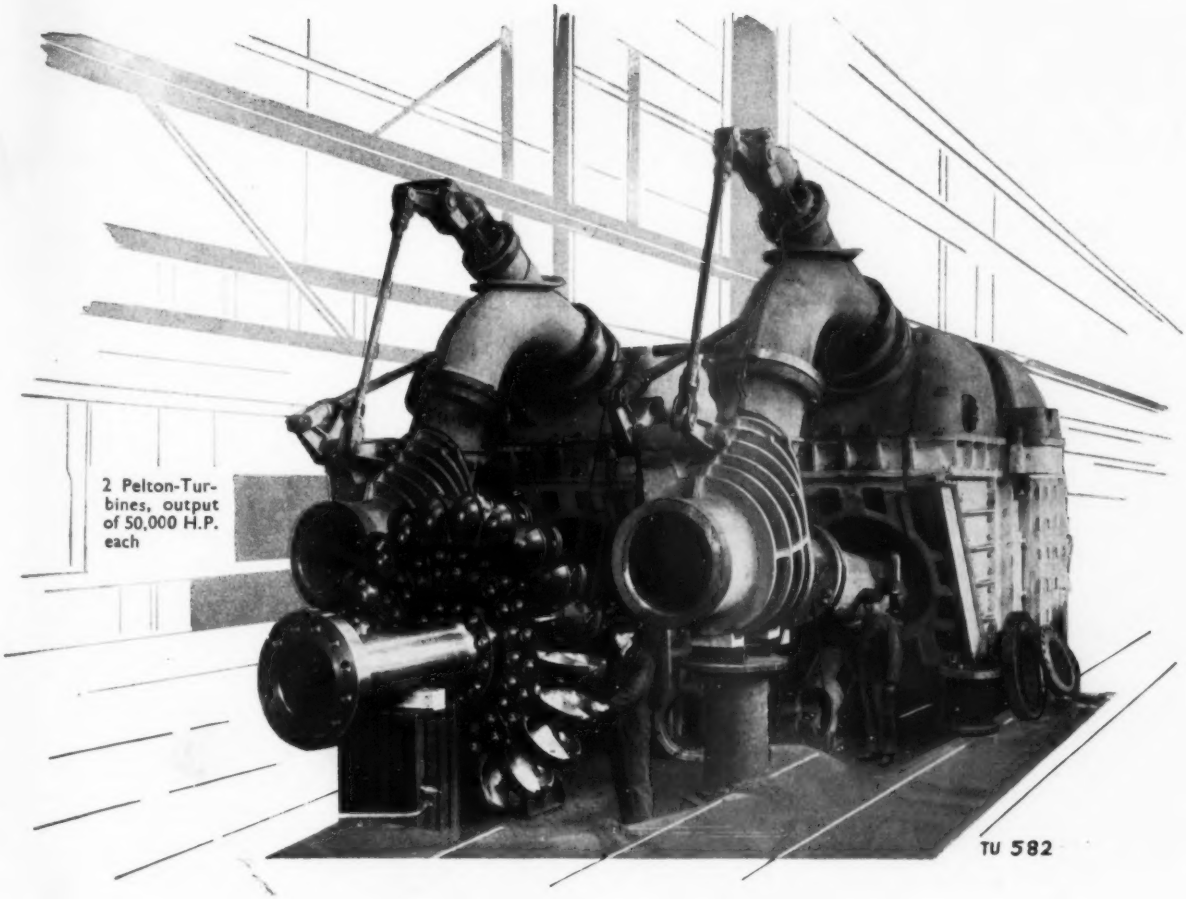

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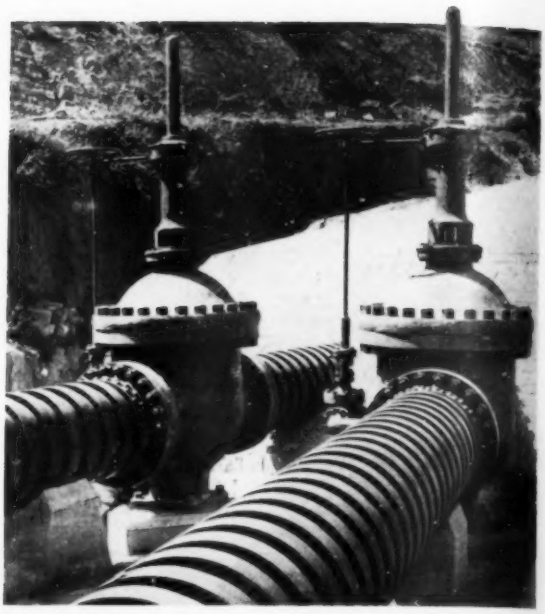

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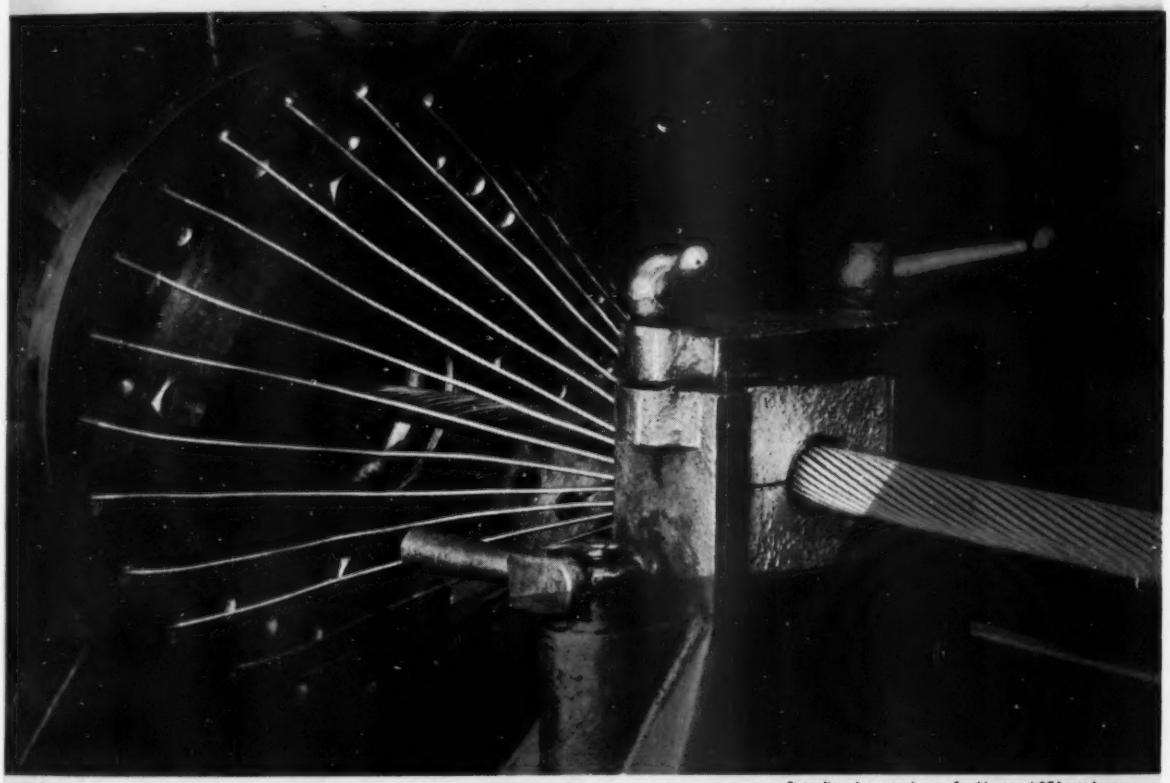

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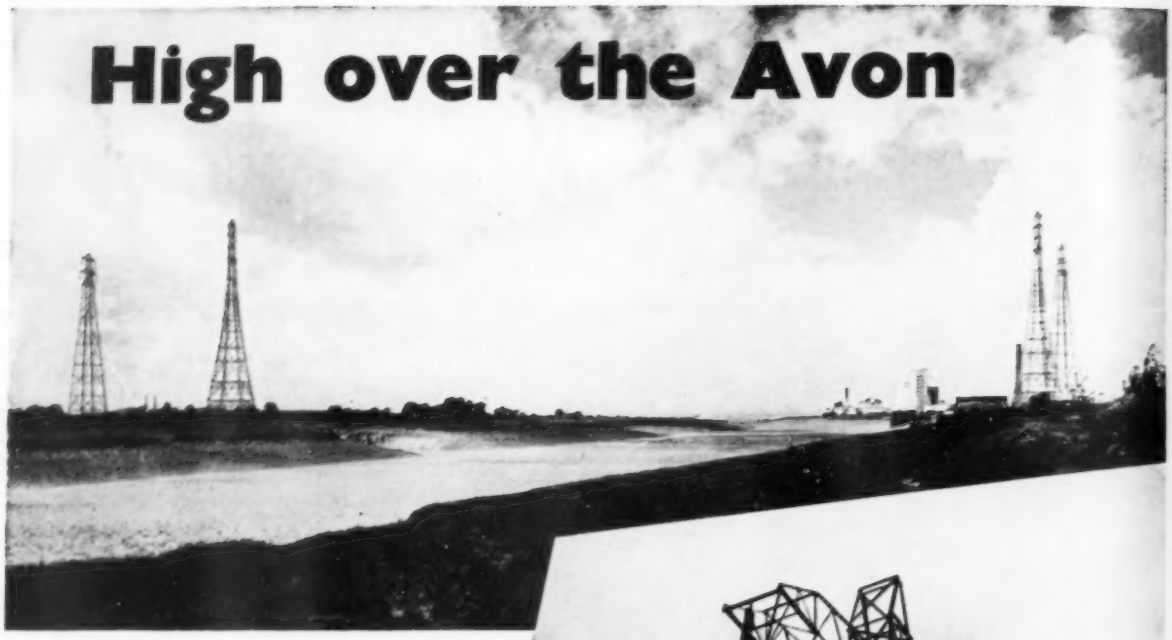

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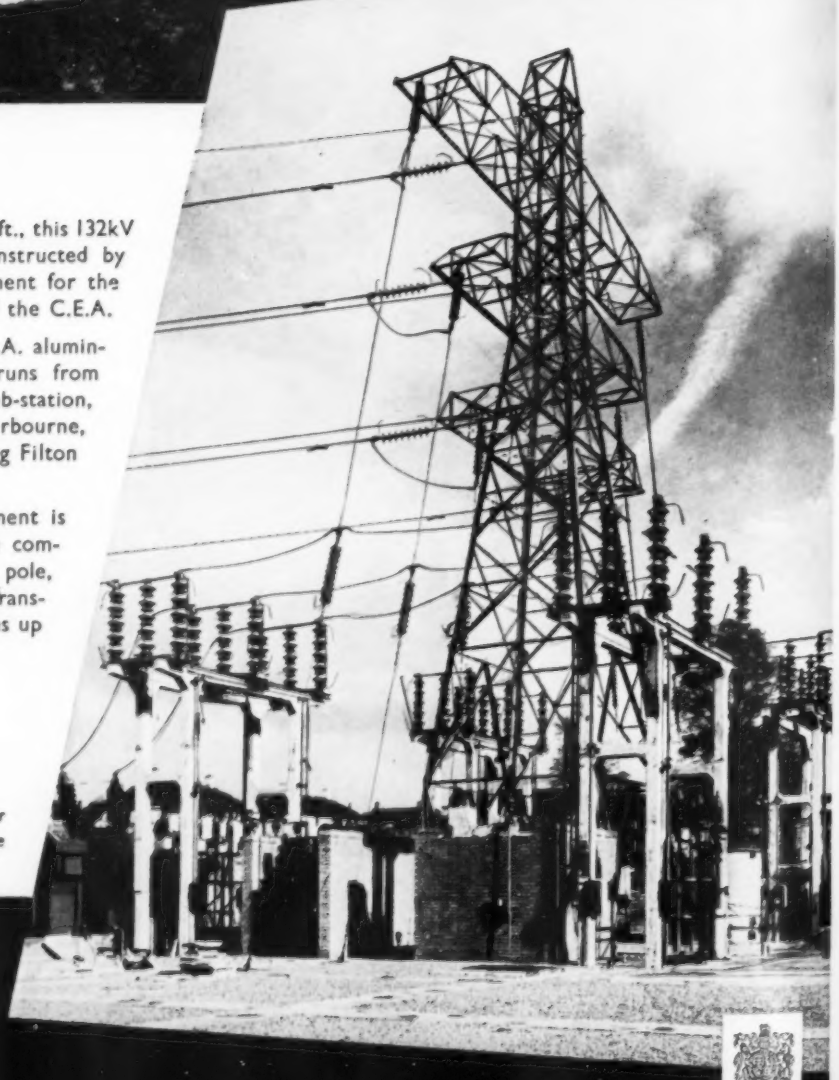

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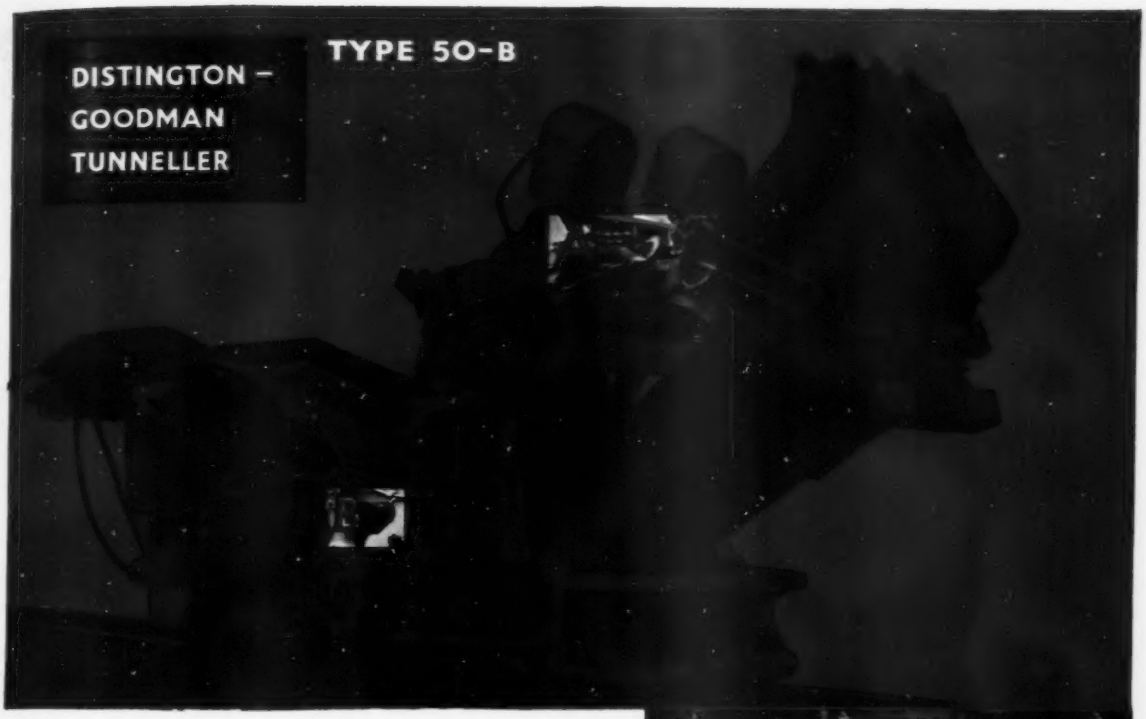

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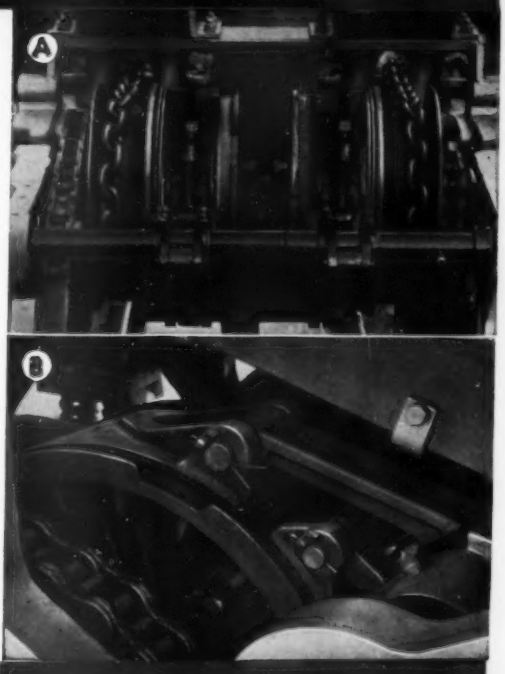
6′	14′ 6″	9′ 8″



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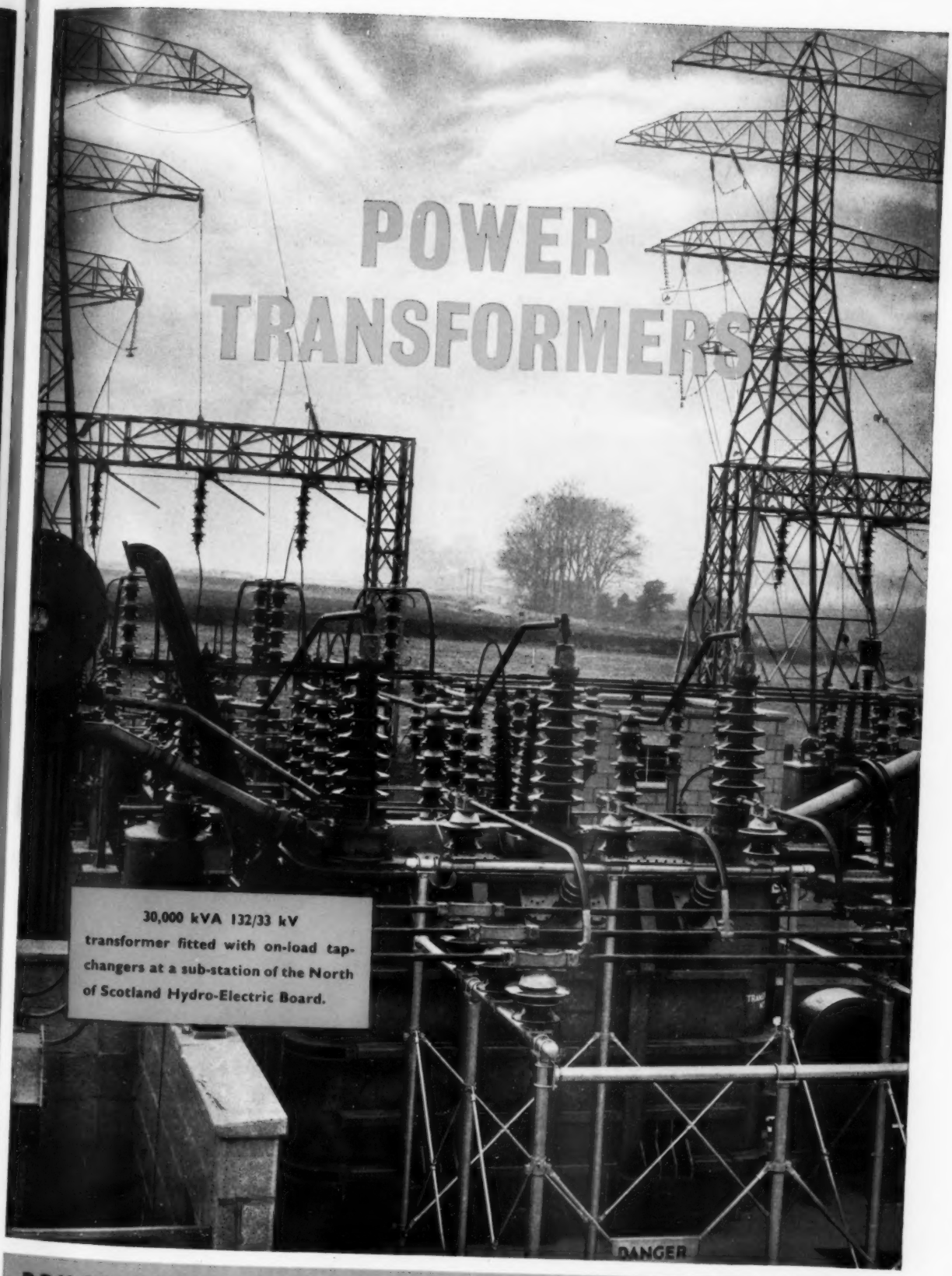

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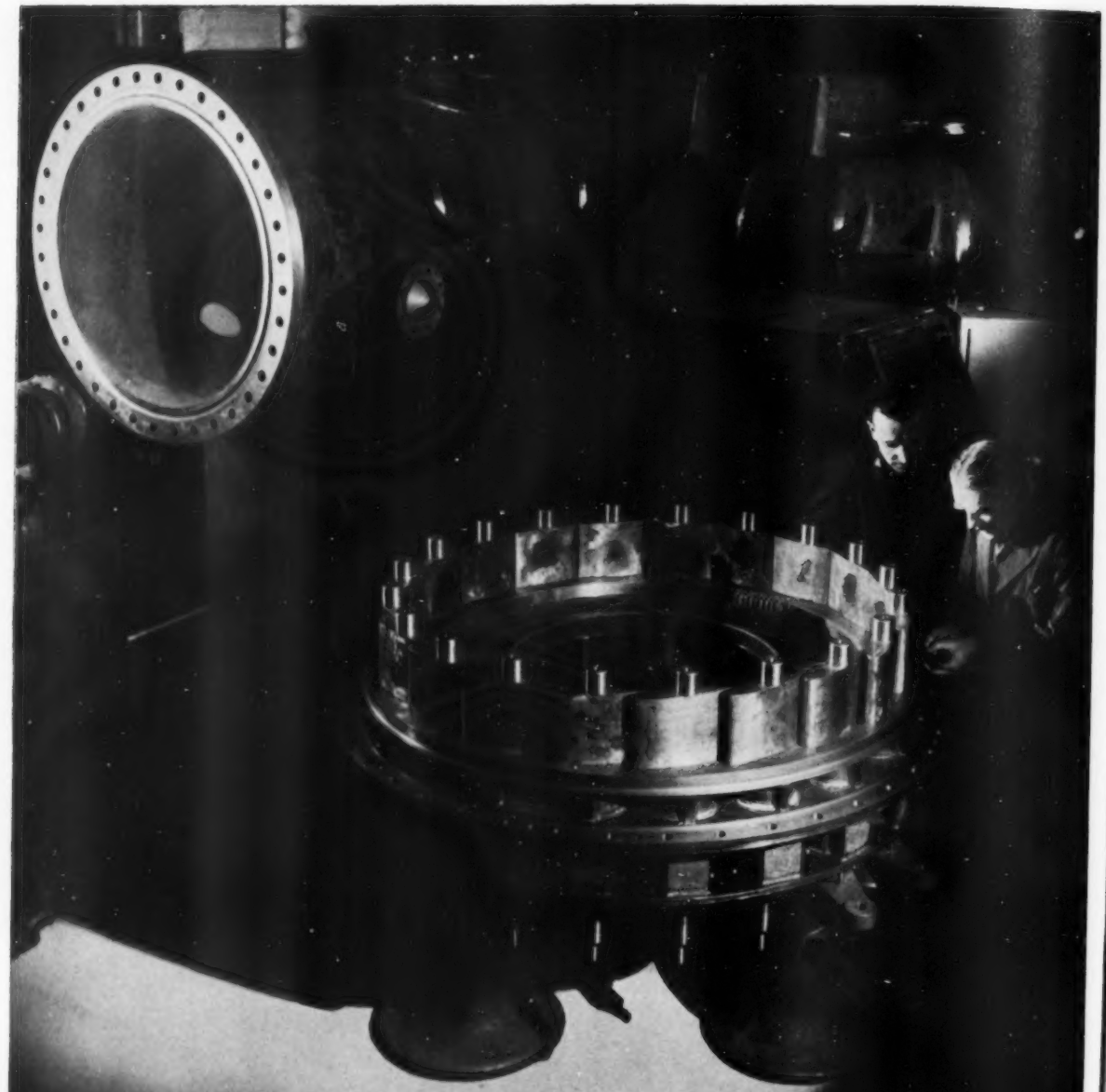

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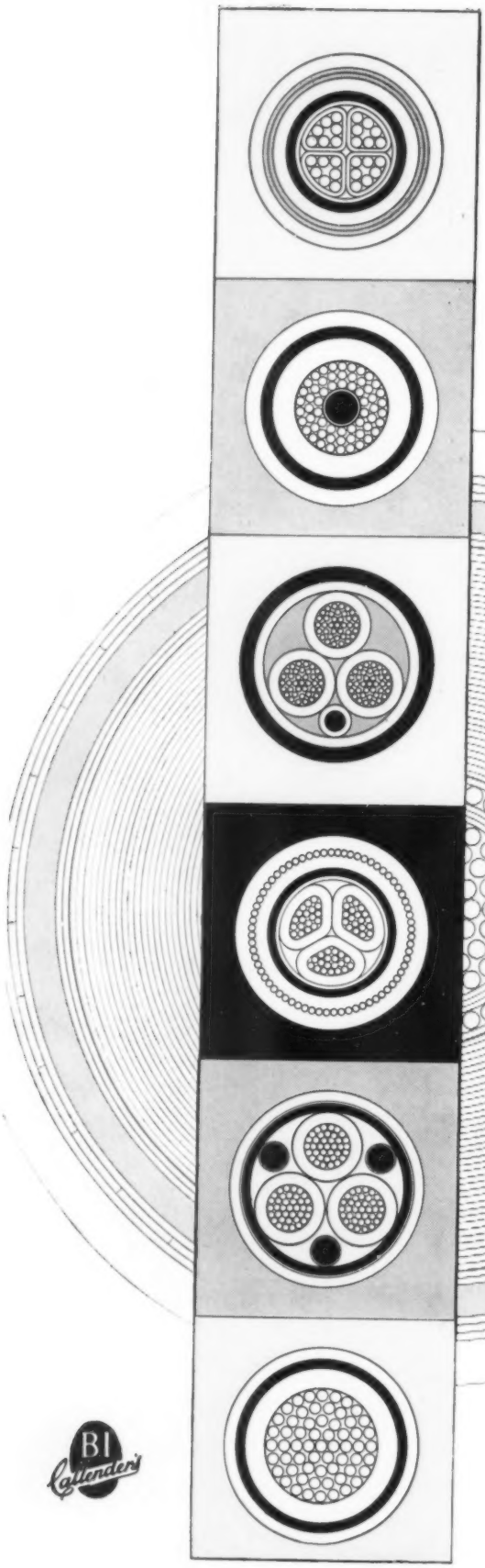

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Silting of Reservoirs

IT is rather remarkable that in technical literature devoted to hydro-electric matters comparatively little has been published about the problem of the silting of reservoirs. True, it is only one of the problems arising from the phenomenon of silt transportation—a subject that is engaging ever-increasing attention—but it is a problem leading to far-reaching consequences. It is an awe-inspiring thought, for instance, that at the present rate of siltation the huge Lake Mead above Hoover dam is likely to be useless for power generation in about 200 years' time, and there are other reservoirs which, according to present prospects, have lives of well under a century.

We would not wish to suggest that hydraulic engineers have been remiss in failing to recognise the problem, or that there have not been valiant attempts to resolve it; but the problem is an intractable one, and there seems to be a disposition in some quarters to accept the inevitable rather than to seek a solution.

For these reasons we attach considerable importance to the investigations carried out by Electricité et Gaz d'Algérie, which are described by Monsieur H. Duquennois on page 174 of this issue. These investigations have had a practical outcome in the development of a technique that, it is claimed, will maintain the Iril-Emda reservoir indefinitely at 80 per cent. of its initial capacity, in spite of the high proportion of silt carried down in this tropical and arid region. Without this technique, it is estimated, 50 per cent. of the capacity would be lost in about 40 years.

The Algerian technique is based on a fundamental analysis of the behaviour of density currents, and aims to make use of the transport energy of the water itself to keep the reservoir clear of deposits. It has two phases, which are described respectively as " approach transport " and " flotation transport." Approach transport replaces the weak incoming flows particularly liable to deposit accumulations at the upstream end of the reservoir by periodic large-capacity scouring waves, which break up these deposits and carry them towards the dam; flotation transport takes advantage of natural or artificially induced density currents by employing a scouring routine which evacuates accumulations and keeps the water density at a prescribed figure.

How far this technique can be applied in other cases can be determined only by a careful analysis of the conditions—for instance, the approach-transport phase, to be fully effective, depends on at least a partial emptying of the reservoir, which may not be feasible in the available circumstances—but as far as the conditions in Algeria are concerned, a practical solution appears to have been found. At any rate, the attention of our readers is commended to Monsieur Duquennois' article, and those vitally interested would be well advised to obtain a copy of the detailed report mentioned at the end of his text.

From a fundamental standpoint, although a scouring technique may be the practical solution, it is somewhat akin to treating the symptom rather than the disease—or, perhaps, like treating malaria in preference to killing the mosquito. The basic solution would be to prevent the river from transporting silt to the reservoir. Unfortunately it is much easier to state this premise than to suggest means whereby such a state of affairs might possibly be realised; in fact, even to suggest that the problem might be attacked from this angle is to invite a sardonic smile. Nevertheless, as is usually the case with the silly answer, the logical correctness of the reasoning remains, and without depreciating the dimensions of the problem it may be possible in certain conditions at least to mitigate the transportation of silt. Our increasing knowledge of fluvial hydraulics may point the way to the execution of up-river works designed to reduce the scour stage of a particular river or to protect erosion-prone sections. Such works, even if feasible, would probably be shockingly expensive, but they might prove economic when balanced against the increase in life of the reservoir. Again, in suitable localities, a marked improvement might be obtained by engaging the services of an agronomist to prevent soil erosion by planting

suitable vegetation or by terracing and similar measures, but this would be inapplicable to arid regions, to mountainous rivers above the vegetation line, and to glacial streams.

An alternative line of attack would be to prevent the silt from falling out of suspension. There are hints of new lines of research in which there is a possibility of causing water to increase its carrying capacity even at lower velocities, but so far nothing has emerged beyond the laboratory stage. Possibly a solution in this sense may lie in the hands of the chemical engineer, although we shudder to think of the probable cost of treating the immense quantities of water involved.

The doubtful practicability of some of the foregoing suggestions may be taken as an index of the intractability of the problem, and points to the need for more fundamental thinking and for much further study of the mechanics, physics and chemistry of silt transportation. Even so, conditions vary so widely that no single solution may provide the final answer. In the meantime, however, we are convinced that the work in Algeria has made an important contribution to our knowledge and to our control over reservoir siltation.

Conference on Power from the Sea

IN connection with the Conference on Power from the Sea, which, as already announced in this journal, will take place from June 10 to 17 under the auspices of la Société Hydrotechnique de France, a volume of the proceedings will be published towards the end of this year. It will be about 500 pages in length, and will contain the papers presented at the Conference together with the discussions, accounts of the sessions, receptions and visits, and the list of members. Copies of this volume can be ordered from the Society at 199 rue de Grenelle, Paris VII, at 4,000 fr. for orders received before June 30 or at 6,000 fr. for orders received after that date.

The Conference will extend from June 10 to 17, and will commence with an excursion to St. Malo and Isles Chausey to inspect the Rance estuary. June 13 to 15 will be occupied with technical sessions in Paris, after which visits will be paid to Argentat and Cambeyrac.

World Power Conference Papers

THE Austrian National Committee of the World Power Conference has now published a booklet giving a list of general reports and papers received by January 10 for presentation at the Fifth World Power Conference to be held in Vienna in June. It contains particulars of the reports prepared by the Austrian General Reporters on the 18 sections into which the papers have been divided, and lists 260 individual papers submitted by the National Committees of 35 member-countries and three international organisations. Copies of this booklet are available through the various National Committees.

New Rio Grande Dam

A NEW international dam is to be constructed across the Rio Grande, to be known as the Anzalduas dam. It will be located about 6 km. north of Reynosa, Tamaulipas, and will cost 50 million pesos. Financing will be shared by Mexico and the United States. The first international dam—the Falcon dam—was dedicated by Presidents Ruis Cortines and Eisenhower on October 19, 1954. Still a third dam, the Diablo, is under study by both governments. This third dam will be located upstream from Piedras Negras. The Mexican Water Resources Secretary, Eduardo Chavez, said that bids for the construction of the Anzalduas dam would be accepted from contractors shortly.

Nymboida River District Scheme

BRITISH, American and French hydro-electric and power engineering companies have been approached for reports on a £20,000,000 hydro-electric scheme in the Nymboida River District of Northern New South Wales, according to the Northern Rivers County Council. The NRCC has already spent £50,000 on preliminary surveys, in conjunction with the New South Wales State Electricity Commission, to determine the hydro-potential of the District.

The project would be carried out in stages and would cascade the waters of the Dorrigo River into the Nymboida River Valley, where a series of dams and power stations would be constructed. The power generated would be fed into the NRCC system.

Shawinigan Annual Report

THE primary peak load on The Shawinigan Water and Power Company's system reached 1,500 MW in 1955, almost 200 MW more than in 1954. The total amount of electricity sold was 9,234,670,800 kWh, 9·8 per cent. more than the previous year. Sales of primary power increased 15·4 per cent, but there was a decrease in sales of secondary energy. New commitments were made during the year for sale of an additional 106,900 kW of primary power.

In view of the continuing growth in demand for electric service in all fields, studies of means of assuring an adequate supply of power for future needs were continued in 1955. These studies led to the recent decision, reached after the Company's 1955 annual report had been prepared, to proceed this spring with construction of the seventh hydro-electric development on the St. Maurice River, at Rapide Sans Nom. The six-unit plant will have a generating capacity of 248 MW and is scheduled to start producing power late in 1958.

A total of $14,994,000 was spent during the year on new construction, compared with $13,345,000 in 1954. The more important projects were: completion of the sixth generating units at La Tuque, Trenche and Rapide Blanc developments; a third high-voltage transmission line from La Tuque to Trois-Rivières; additions to Quebec Terminal Station; initial work on new terminal stations at Chaudière and at Kingsey; construction of a new office and service building at Joliette, and additions to the transmission and distribution networks, including rural lines.

A total of 8,175 new customers were added to the system during 1955, bringing the total number served at the end of the year to 222,817 in 612 municipalities. The average annual consumption of electricity by residential customers increased to 2,380 kWh in 1955 from 2,163 kWh in 1954.

The consolidated balance sheet shows that the working capital at the end of 1955—excess of current assets

over current liabilities—totalled $17,924,813, as against $11,101,453 in 1954. Fixed assets increased by $13,423,753. The outstanding funded debt was reduced by $1,514,000 during the year, through the operation of the Sinking Fund. At the end of the year the accumulated total of earnings retained and invested in the business was $21,687,369, as compared with $17,725,037 at the end of 1954.

Dry weather during the summer affected water conditions in the St. Maurice Valley and necessitated curtailment of sales of secondary power. The amount of water in storage at the year end was close to the long-term average.

Aswan Dam Technical Conference

A WEEK'S conference was held in March at the Grenoble Laboratories of the Neyrpic group of companies to discuss the technical problems associated with the design of the Aswan high dam. The conference was organised to determine the essential features of the cofferdam, the diversion tunnels, and the diversion sluices. The preliminary works will comprise the driving of seven tunnels, 16·5 m. in diameter and of a total length of 14 km., to allow an irrigation flow of 1,800 cu. m. per sec. and an exceptional flood flow of 11,000 cu. m. per sec. The problems involved are being studied at the Laboratoire Dauphinois d'Hydraulique by a series of scale models.

Participating in the conference were Colonel Samir Helmy, Secretary General, and Dr. Mohamed Ahmed Selim and Dr. Hassan Zami, members of the Sadd el Aali Authority; M. Coyne (France), Professor Pruss (Germany) and Professor Straub (U.S.A.), consultants to the Sadd el Aali Authority; Mr. Guthrie Brown and colleagues, of Sir Alexander Gibb & Partners (England); M. Furuskog and colleagues, of V.B.B. (Sweden); and M. Danel and colleagues, of la Société d'Etudes SOGREAH (a member of the Neyrpic group). The conference was officially terminated by Wing Commander Hassan Ibrahim, Egyptian Minister of State and President of the Sadd el Aali Authority.

Progress in Victoria, Australia

THE Annual Report up to June 30, 1955 of the State Electricity Commission of Victoria, Australia, reveals encouraging progress, both financially and technically, but refers to the difficulty of financial planning to ensure sufficiently rapid development to keep pace with the anticipated growth in electrical demand and to provide a requisite reserve of plant.

The Commission's power resources are based predominantly on fuel, in which brown coal plays a vital role, but important progress was made during the year on both the Kiewa and the Eildon hydro-electric projects. In the Kiewa scheme work was recommenced on the Rocky Valley dam; the cut-off wall was 25 per cent. completed and the placing of earthfill continued throughout the summer. In the No. 1 Development excavation for the headrace tunnel was completed for a 96 MW station planned for operation in 1958/59. No. 3 Development, a 26 MW station at Bogong Creek, has been in operation since 1944. In No. 4 Development the civil works were largely complete and two 15·4 MW sets were placed in service during the period under review, a third since the close of the year, and the fourth was due for installation before the winter of 1956. Work was proceeding on a diversion tunnel from the West Kiewa River to No. 4 power station, and was about 30 per cent. complete.

At Eildon two generators from the old Sugarloaf power station were installed in August 1954 and will provide 16 MW of peak power. Installation was commenced of two 60 MW sets, to be in operation in 1956.

Victoria's share in Snowy Mountains power is expected to commence to materialise early in 1959.

Blenio Valley Development

WE understand that the contracts for the first major sections of the Blenio Valley Development were awarded in March, and construction work is expected to begin in the course of the coming summer. This development is to have an installed capacity of 404,000 kW in four power stations and its main promoters, besides several leading electricity undertakings, are the cantons Tessin and Bale-Town and the Zurich Corporation. Berne Corporation is also interested. Average production is assessed at 488 million kWh in winter and 493 million kWh in summer.

Wadi Tharthar Barrage Inaugurated

KING Feisal of Iraq, on April 2nd, inaugurated the barrage on the River Tigris at Samarra, 70 miles north-west of Baghdad. This development is intended primarily as a means of preventing the disastrous flooding on the Tigris, and impounds the flood water so that it can spill over desert land to the west of the river, finally passing through an escape channel to the Wadi Tharthar depression 43 miles away. A dyke, 31 miles long, prevents the water flooding the land to the south and returning to the river.

The contract for the escape channel, dyke and subsidiary works was let in 1951 to Balfour Beatty & Co. Ltd., and has been one of the biggest single earth-moving contracts in the world. It involved moving 52 million cu. yards of earth, and was completed in the original contract time of 50 months, although the escape tunnel was enlarged to a capacity of 325,000 cusecs after the flood of 1954.

As originally conceived, the scheme was purely for flood control, but at the suggestion of Zublin A.G., of Stuttgart, who built the barrage, a power station has been incorporated in the dam but it is not expected to be commissioned until next year. The 53 sluice gates, each about 40 ft. wide, were supplied by Ransomes & Rapier Limited.

When completed, the scheme will have cost about £16 million, of which £9 million will have been absorbed in the barrage and power station.

Uganda Electricity Board

IN its Report for the year ended December 1955, the Uganda Electricity Board states that nearly 80 million kWh, or 99·53 per cent. of the electricity sold, were generated at the Owen Falls hydro-electric station. The main civil-engineering works at Owen Falls were substantially completed by the end of the year. With the construction of the railway viaduct it was possible to raise the water level between Owen Falls and Lake Victoria so as to load the turbo-alternators to their

full output. With this raising of the water level, the Ripon Falls, historical source of the Nile, virtually disappeared. Four 15 MW sets have now been commissioned at Owen Falls; work has commenced on the installation of another two 15 MW sets and a further two have been ordered, making eight in all. The ultimate capacity of this ten-set station is 150 MW.

On present estimates it appears that the start on construction of a second power station might be justified by 1960. A survey of the hydro-electric potential of the Nile in a nineteen-mile stretch just below Owen Falls has shown that there is a total potential output, including the existing station, of 650 MW to meet future demands for electricity. The additional power can be developed in two or three stages and a detailed examination of one site is now being made. Surveys have taken place of some water-power resources in Western Uganda, for generating electricity for local distribution.

The possibility of thermal generation is also being examined for districts without suitable hydro-electric resources which are for the time being outside the range of economic transmission from Owen Falls.

Sir Charles Westlake retired from the chairmanship of the board in September, after having served in that office since 1948, and was succeeded by Mr. W. D. D. Fenton.

Franco-Swiss Power Exchanges

THE 225 kV line linking Genissiat with the power stations of the Ouest-Suisse and Mauvoisin concerns was put into service at about the same time as the 225 kV Valais-Col du Sanetsch-Mühleberg line. These two lines are directly connected, and they have recently proved their usefulness when the hydrological situation compelled Switzerland to draw substantial blocks of power from the EDF system. In addition to providing new possibilities of power exchanges between the two countries, the Genissiat link will operate as a reserve source of supply for Geneva and its suburbs.

British Columbia Power Corporation Report

A BUOYANT situation is disclosed by the 1955 Annual Report of British Columbia Power Corporation Limited, of which B.C. Electric is a subsidiary. Gross revenue was $63·4 million, an increase of 7·1 per cent. on 1954, and operating expenses $48·8 million, an increase of 3·3 per cent. Customers for electricity supply rose by 14,386 to 280,079, and units sold, exclusive of power exported, were 2·2 billion kWh, an increase of 16 per cent.

The raising of La Joie dam to its final height of 282 ft. was finished in October 1955. The reservoir it creates is sufficient to allow the four 45,000 kW generating units at the Bridge River plant to operate at full capacity. The single unit at Seton Creek of 42,000 kW, it is expected, will be in operation by mid-1956. Water impounded behind La Joie dam will serve this plant after being used in the Bridge River plant. Work was continued throughout the year on the Cheakamus project, which provides for the diversion of water from the Cheakamus River through a 6¼-mile tunnel to the Squamish River. At the year end approximately 2½ miles of this tunnel had been completed and work had been started at the site of the diversion dam. The generating plant, on the Squamish River, will comprise two units of a combined capacity of 140,000 kW. Completion is planned for the autumn of 1957.

A second transmission line from Bridge River to Vancouver is being constructed, and manufacture of the submarine cable to connect the systems of the Mainland and Vancouver Island, which is scheduled to be laid in the summer of 1956, is well in hand.

Reference is also made in the Report to the Powell River transmission line described in our January issue and to the formation of the new subsidiary, Western Development and Power Limited, which we recorded last month.

A New Swiss Hydro Concern

THE Kraftwerke Reichenau A.G., Tamins, founded on December 23, 1955, with a capital of 1 million Sw. Fr., is to devote special attention to the hydro-electric development of the headwater regions of the Rhine.

Transmission-Line Research

A RESEARCH Association, initiated by Energie Ouest-Suisse in co-operation with the Material Testing Station of the Lausanne Technical University (LEMEPUL), was founded last September in Lausanne for the purpose of establishing basic design and construction data for overhead transmission lines and their equipment. A tower testing station, now in course of construction, is expected to be put into service very shortly. A substantial number of Swiss electricity undertakings, engineering concerns, and other interested organisations are now affiliated to the Association, which has its seat at the LEMEPUL Office, Bel-Air Métropole 10, Lausanne.

Mexican Power Expansion

THE Mexican Light and Power Company will have an operating capacity of 1 million kW when its present expansion programme is completed early in 1958. The total cost of the expansion programme is estimated at U.S. $200 million.

Roxburgh Ready by End of August

ACCORDING to the New Zealand Minister of Works, the Hon. W. S. Goosman, the Roxburgh hydro scheme will be in operation with three of its four generators about the end of August this year. Three generators are already installed, but some parts of the fourth generator have still to arrive from overseas.

Mr. Goosman also said that the construction of a hydro-electric power station at Benmore, on the Waitaki River, will proceed whether or not a submarine cable across Cook Strait proves practicable. Investigations will be pushed ahead for the construction of another large generating station additional to Roxburgh and Benmore, if the Cook Strait cable is undertaken. Benmore should be in operation before any possibility of a power shortage arises in the South Island. After Roxburgh starts there should be no predictable shortages in the South Island.

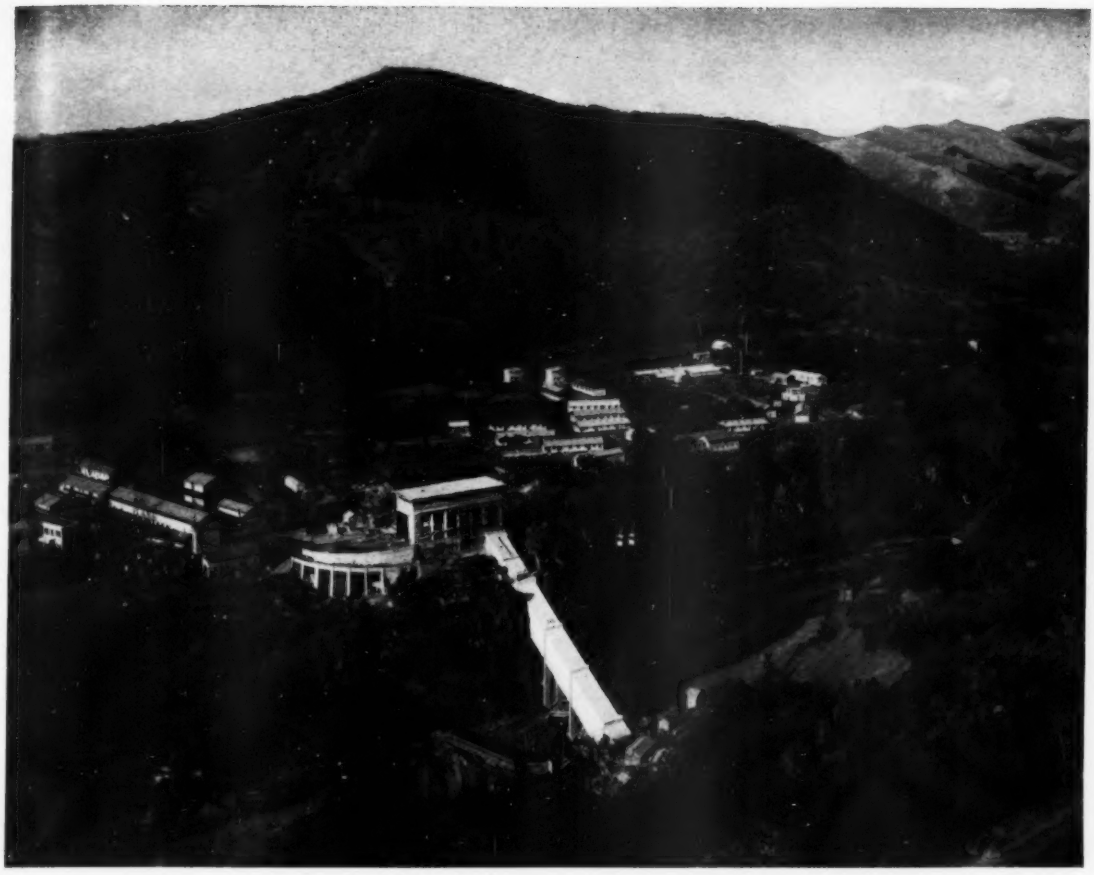


Fig. 1. General view of the surface buildings at Montpezat

The Montpezat Scheme

Leading particulars are given of this interesting French scheme, situated in the Massif Central, in which the headwaters of certain tributaries of the Loire are diverted into the Rhone watershed

By WALTER T. STOREY, B.A. (Cantab.)

PART ONE

IN the Montpezat region of the Massif Central the mountainous barrier of the Cevennes separates the Atlantic watershed of the Loire from those rivers which join the Rhone to flow into the Mediterranean. The Loire and its tributaries naturally tap a larger proportion of the rainfall but the upper reaches do not readily lend themselves to hydro-electric exploitation because of the relatively gentle gradient. If these waters were to be led through to the Mediterranean watershed, however, a considerable head could be developed over a short distance. Such a solution has been realised in the Montpezat undertaking.

The headwaters of the Loire have been tapped by a retaining dam at La Palisse and two further dams on the Gage and the La Veyradère respectively have brought in the waters of these tributaries. The La

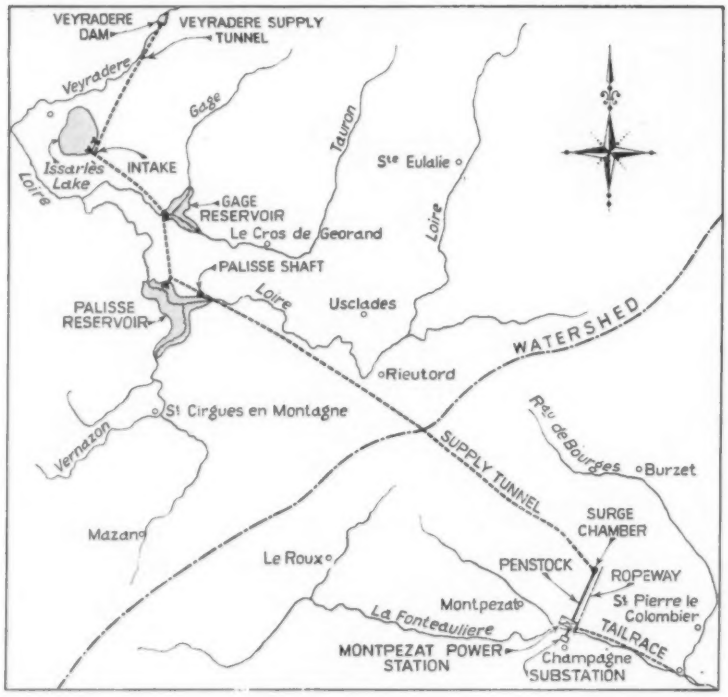


Fig. 2. Sketch map showing position of Montpezat power scheme in the Massif Central

Palisse and Gage dams function as storage reservoirs but the capacity of that on the La Veyradére is negligible. The utilisation of a lake occupying an ancient volcanic crater at Issarlès has greatly contributed to the storage capacity of the scheme and hence to its importance as a producer of firm power. In all, the 200 sq. km. of the Atlantic side of the watershed yield an average flow of 8 cu. m. per sec., the total average flow at Montpezat station being 22 cu. m. per sec. This is brought through the Cevennes by over 20 km. of tunnelling and is delivered to the underground power station at Montpezat, on the Rhone side of the watershed, under a 640 m. head. Here generating plant having a total of 116,000 kW has been installed and this should enable 300 million kWh to be developed during an average year. The total storage capacity amounts to approximately 45 million cu. m. of water which represents some 60 million kWh.

The Underground Power Station at Montpezat

The power station has been ex-

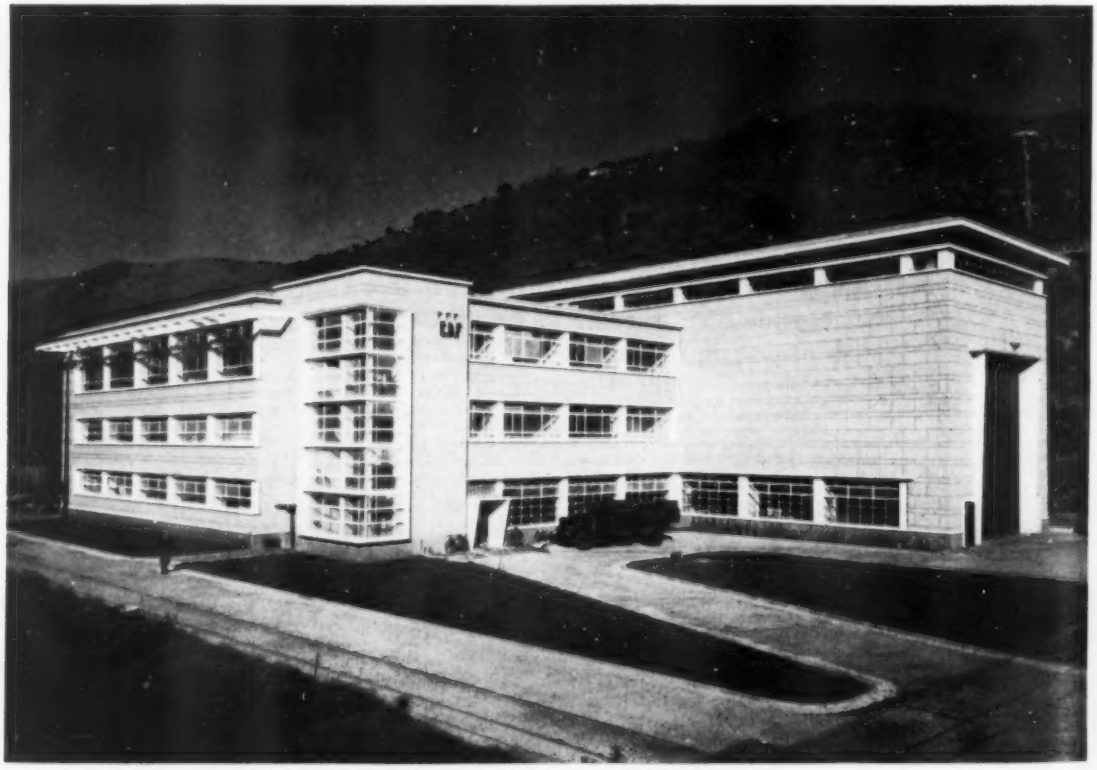


Fig. 3. Offices and surface buildings serving Montpezat power station

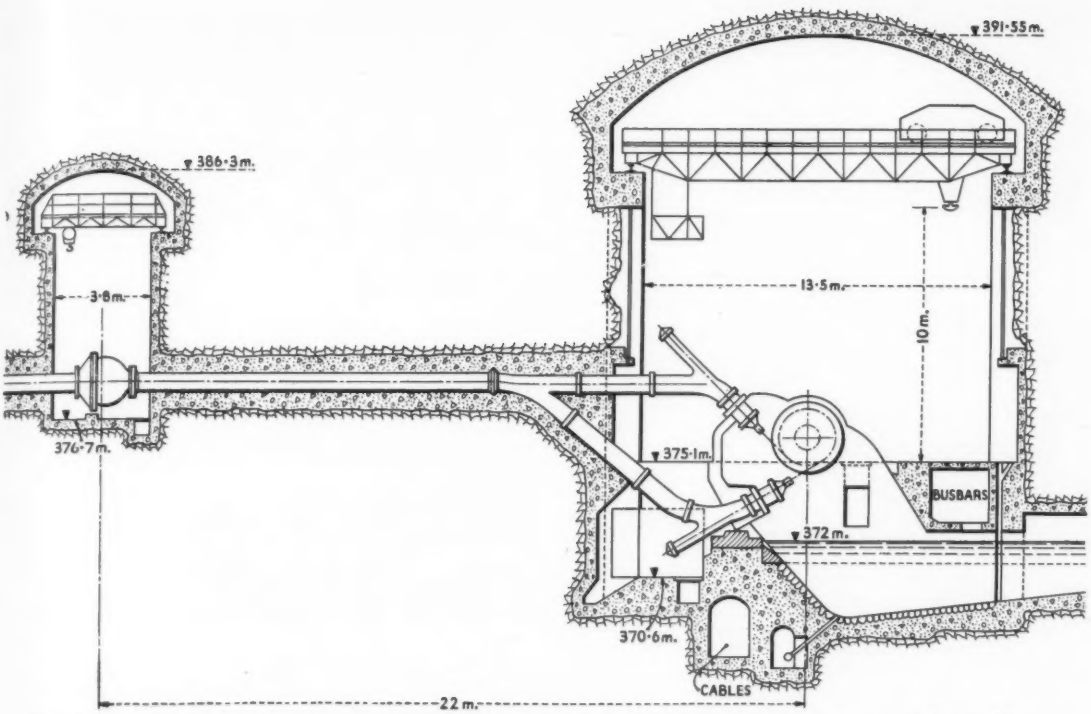


Fig. 4. Sectional elevation of power house and valve chamber along centre line of one of the turbines

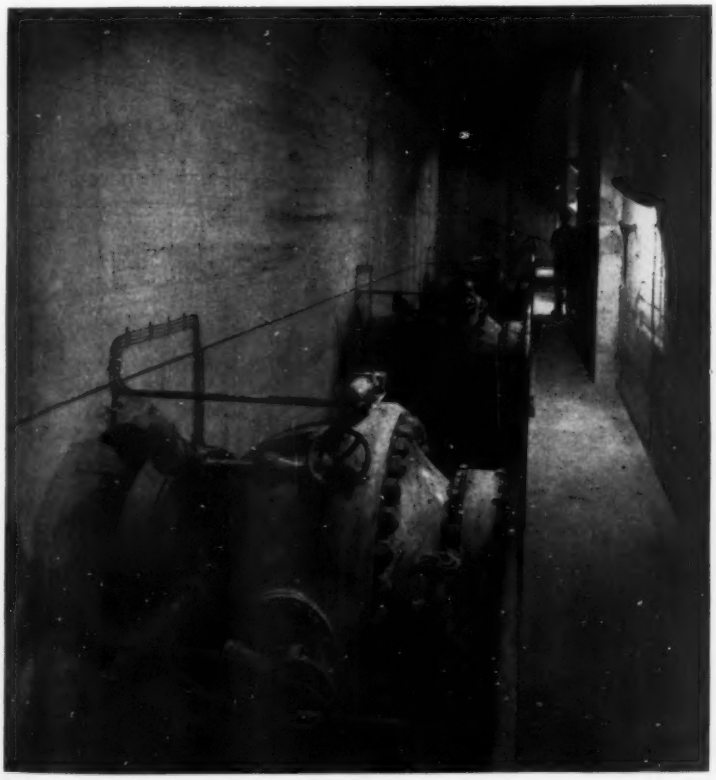


Fig. 5. A view along the valve gallery

cavated in a compact granite rock at about 60 m. below the bed of the Fonteaulière which is a small tributary of the Ardêche. The main hall which houses the turbines and generators is of large size (65 m. × 18 m. × 26 m.) and could readily be extended if the scheme were to be enlarged. All the turbine valves are placed in a parallel gallery (55 m. × 8 m. × 4 m.) which, as a precautionary measure, is sealed off from the main hall when the penstock is in use. The four valves, corresponding to the four divisions of the penstock, are each 1 m. in diameter and are of the spherical type.

There are two generating sets, arranged horizontally, which are designed to operate at 428 r.p.m. under a 625 m. head, the runaway speed being 820 r.p.m. As will be seen from the section, Fig. 8, each set comprises two overhung Pelton runners mounted on either side of a two-bearing alternator. Two jets are provided per runner and each is capable of delivering 2·75 cu. m. of water per sec., giving an output of 15,500 h.p. per jet. The two turbines are identical and were supplied jointly by Cie de Fives-Lille and by Escher Wyss Limited, the Oerlikon Engineering Com-

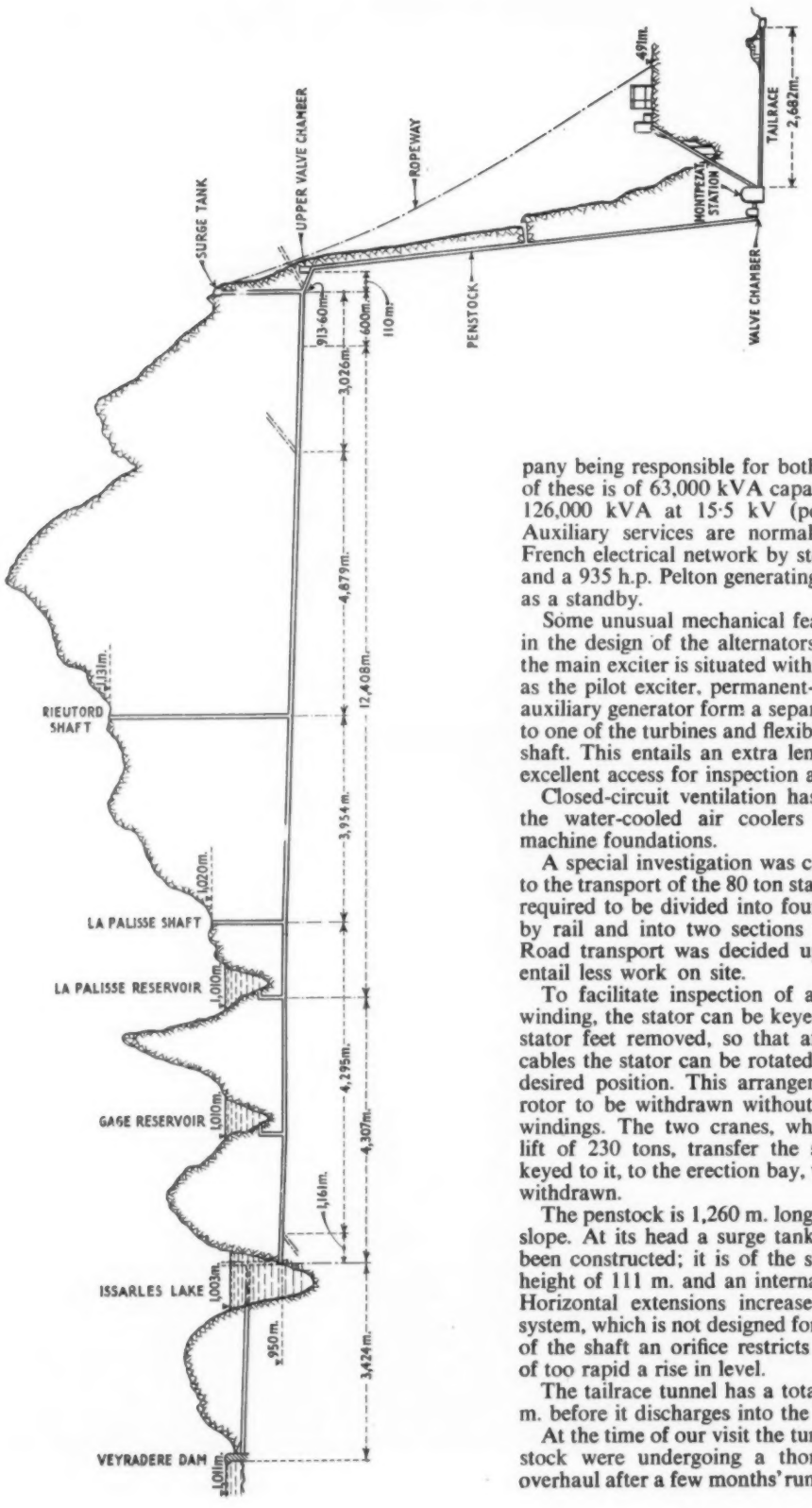


Fig. 6. Schematic profile of Montpezat scheme

pany being responsible for both the alternators. Each of these is of 63,000 kVA capacity, making a total of 126,000 kVA at 15·5 kV (power factor = 0·93). Auxiliary services are normally supplied from the French electrical network by step-down transformers, and a 935 h.p. Pelton generating set has been installed as a standby.

Some unusual mechanical features are to be found in the design of the alternators. Reverting to Fig. 8, the main exciter is situated within the bearings, whereas the pilot exciter, permanent-magnet generator and auxiliary generator form a separate unit mounted next to one of the turbines and flexibly coupled to the main shaft. This entails an extra length of 1 m. but gives excellent access for inspection and maintenance.

Closed-circuit ventilation has been provided, with the water-cooled air coolers arranged within the machine foundations.

A special investigation was carried out with regard to the transport of the 80 ton stator, which would have required to be divided into four sections for carriage by rail and into two sections for carriage by road. Road transport was decided upon because it would entail less work on site.

To facilitate inspection of all parts of the stator winding, the stator can be keyed to the rotor and the stator feet removed, so that after disconnecting the cables the stator can be rotated with the rotor to any desired position. This arrangement also enables the rotor to be withdrawn without disturbing the stator windings. The two cranes, which have a combined lift of 230 tons, transfer the stator, with the rotor keyed to it, to the erection bay, where the rotor can be withdrawn.

The penstock is 1,260 m. long and has a 46 per cent. slope. At its head a surge tank of simple design has been constructed; it is of the shaft type with a total height of 111 m. and an internal diameter of 3·50 m. Horizontal extensions increase the capacity of the system, which is not designed for overflow. At the base of the shaft an orifice restricts the flow in the event of too rapid a rise in level.

The tailrace tunnel has a total length of over 2,680 m. before it discharges into the Fonteaulière.

At the time of our visit the turbines, valves and penstock were undergoing a thorough inspection and overhaul after a few months' run, and apart from some

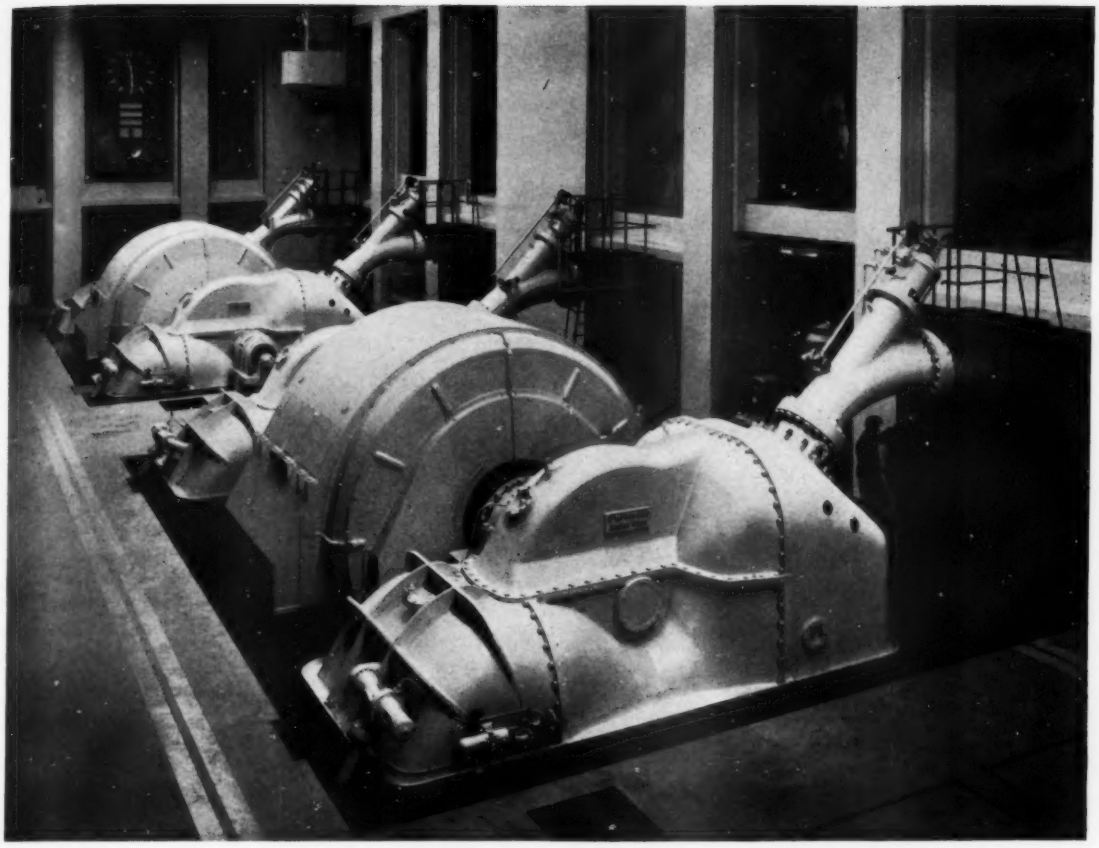


Fig. 7. Montpezat machine hall, showing the Escher-Wyss/Oerlikon 63,000 kVA sets

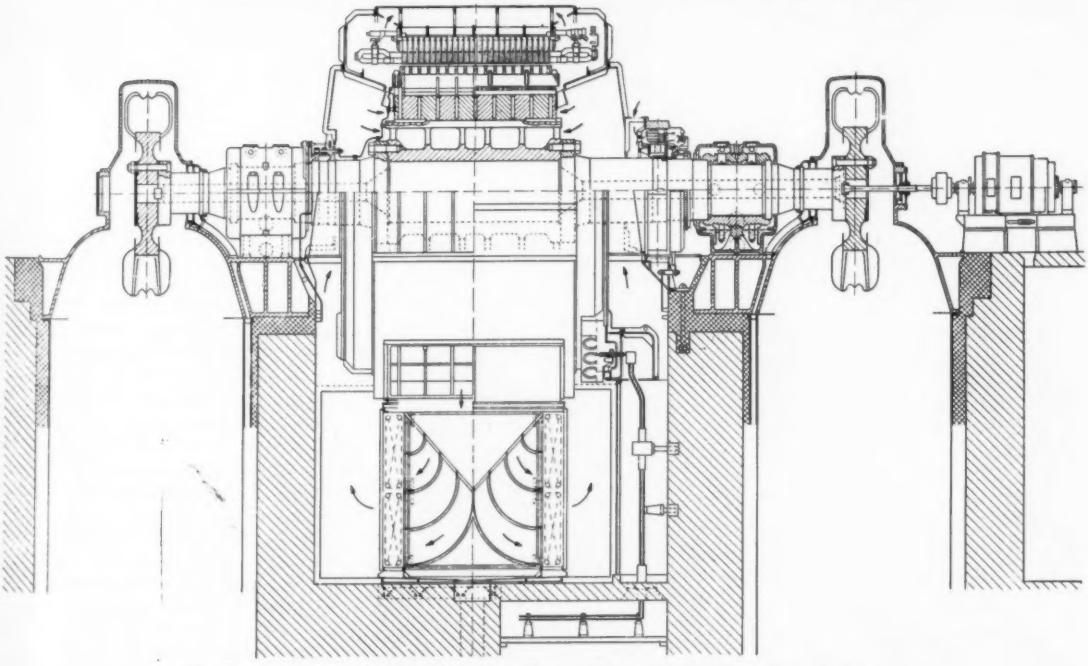


Fig. 8. Section through one of the Escher-Wyss/Oerlikon generating sets

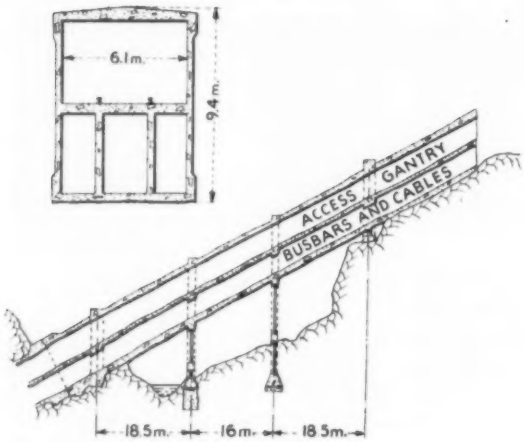


Fig. 9 (above). Cross-sectional elevations of gantry bridge over Fontallière river

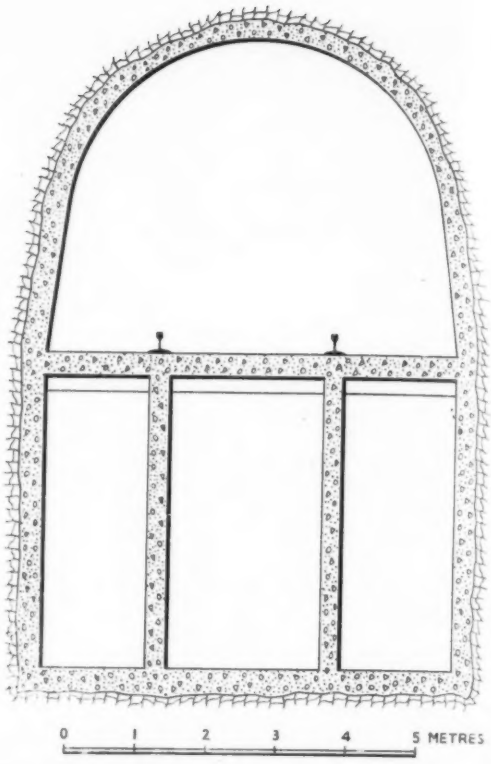


Fig. 10 (right). Access gallery to power station

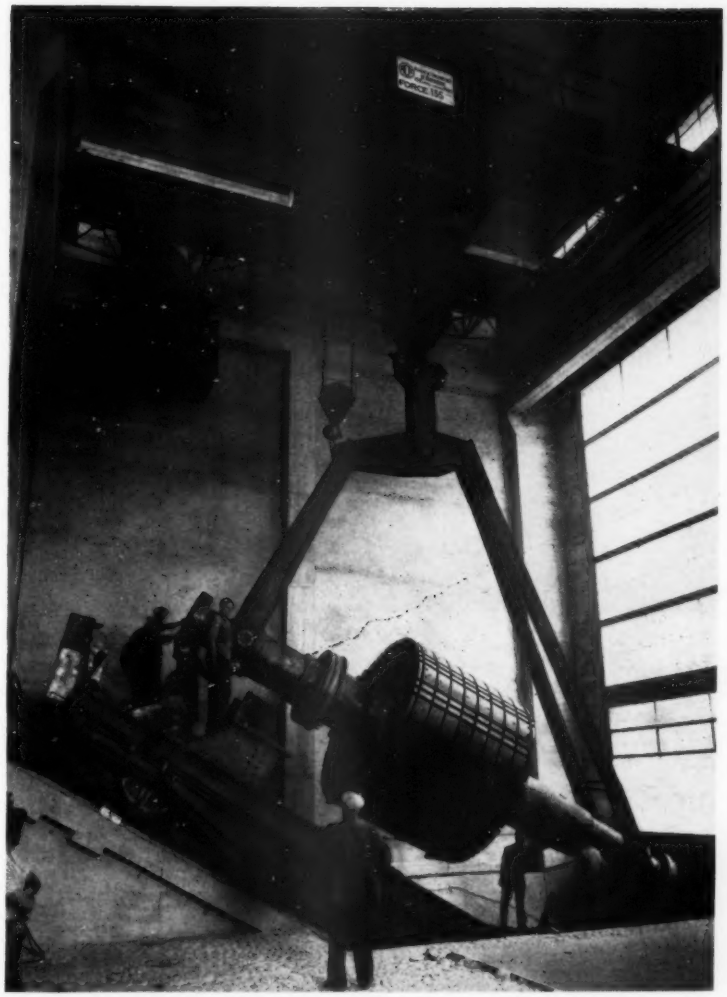
Fig. 11 (below). The access gallery showing travelling bogie and conductor rails

adjustments which were restricted to the valves, all was found to be in a very satisfactory condition.

Access, Controls and Transformation

Whereas the underground power station is excavated beneath the left bank of the Fonteaulière, the building housing the controls and dealing with the main supply services is perched high up on the right bank. Access is gained through a slanting gallery, having an inclination of 55 per cent., which bridges the Fonteaulière. The upper compartment of this structure forms a gantry which is capable of handling the heaviest items of equipment used in the power house. It is equipped with a travelling bogie which is operated on the rack-and-pinion principle (Fig. 11), power being provided by an electric motor which picks up its current from a series of live rails placed midway between the bearing rails. Fig. 1 gives an exterior view of the structure and Fig. 12 shows the rotor, weighing 135 tons, in the act of being loaded on to the bogie before being taken down the inclined gallery to be transferred to the power house. The lower part is divided into three parallel

Fig. 12. Rotor being loaded on to bogie



compartments which serve the multiple purpose of carrying the aluminium bars which convey the current from the generators to the transformers, all the control, communication and protective-gear cables, and also the vitiated air from the ventilation system. Fresh air is drawn in through a special shaft driven entirely in the left bank.

The control room is something of a showpiece; complete control of the valves, generators, voltage adjustment and of the synchronising equipment may be effected from here. Like the main hall of the underground power station, it has also been designed to allow for further extension. An enlargement of the Montpezat scheme has in fact already been envisaged and should these additional projects be realised the total production of the plant may be brought up to 1,000 million kWh per annum.

The transformers have been supplied by Brown, Boveri & Co. Ltd. and consist of three main single-phase transformers which convert the 15·5 kV alternator voltage to the 225 kV grid voltage; there is also an additional pair of three-phase 63,000/380 V transformers, with a capacity of 150 kVA, to feed the plant's auxiliary network.

(To be continued)

The Glen Shira Project

An important paper on the Glen Shira hydro-electric project was read on 17 April before the Institution of Civil Engineers by John Paton, M.I.C.E., a partner in the firm of Babtie, Shaw & Morton, the consulting engineers for the scheme. An interesting feature of this Scottish scheme is that pumped storage is used for balancing. The topography of the site favoured a main reservoir at 1,108 ft. O.D. having a live storage of 750 million cu. ft., and a lower reservoir at 970 ft. O.D. with a live storage of only 55 million cu. ft., which feeds the North of Scotland Hydro-Electric Board's first large underground station at Clachan, the turbine runner being at 10·5 ft. O.D. Between the two reservoirs a small power station—Sron Mor—has been placed, containing a set consisting of turbine, motor/generator, and pump. This station not only makes use of the head between the two reservoirs, but, when necessary, prevents overspill from the lower reservoir by pumping back to the main reservoir.

The main dam is of the round-head buttress type, 2,250 ft. long at crest and 133 ft. above lowest foundation, and comprises 37 buttresses at 50 ft. centres. The reasons for adopting this type, and the leading design considerations and construction procedure, were outlined in Mr. Paton's paper.

The site for the lowest reservoir was not particularly favourable, although the provision of such a reservoir was fully justified on engineering and economic grounds. The only feasible site involved the construction of a dam in two separate sections, one located immediately upstream of a waterfall. For this section concrete gravity construction was adopted, special attention being given to the design of the spillway to avoid undermining the dam. The other section was in earthfill, and owing to variations in the character of the fill, pore-pressure measuring equipment was installed.

The main tunnel is 21,050 ft. long, 10 ft. in diameter, and is succeeded by a surge chamber and an inclined pressure shaft which is steel lined.

The power station houses a 40 MW vertical Francis set operating at 428 r.p.m. under a head of 960 ft. It is the largest-capacity set so far installed in the United Kingdom.

Fig. 1. Eril-Emda dam

New Methods of Sediment Control in Reservoirs

Important investigations carried out by Electricité et Gaz d'Algérie have led to the adoption of procedures that are proving highly effective in the control of sediment in reservoirs

By H. DUQUENNOIS,
INGENIEUR DES PONTS & CHAUSSEES, CHEF DU SERVICE DES ETUDES GENERALES ET RECHERCHES D'ELECTRICITE ET GAZ D'ALGERIE

ECONOMISTS are rightly concerned with any loss of natural resources, and an instance of particular interest to hydro-electric engineers is the silting up of reservoirs. The more arid the climate the more important the problem becomes because earth erosion takes place the more easily when the rainfall is irregular. Numerous methods of control have been proposed. Those applied or in course of study by Electricité et Gaz d'Algérie can be defined as utilising, with or without transformation, the natural transport energy available in the reservoir itself.

The finest solid particles provide their appropriate transport energy and, thanks to density currents, travel right up to the dam. To remove them it is sufficient to drain them off before the silt consolidates. The coarsest particles become distributed in the upper reaches of the reservoir, and are picked up again to a greater or less extent by variations in the water level, the river flow, the size analysis of the particles, and the degree of consolidation of the deposits. Their transit downstream can be effected partially or completely by transformation of the transport energy of the water, either with or without changes in the conditions of usage of the reservoir.

Density Currents and Silt Evaluation

In arid regions river flows are characterised by flood waves followed by after-flows which exhaust themselves fairly rapidly. These are the floods which transport by far the largest proportion of solid material, those which follow the dry season being particularly highly loaded with fine particles in suspension. In Algeria densities of 1·130 and over have been observed in the autumn.

Let us take:—

d = the density of the water flowing into the reservoir, where we may assume the density of the stored water to be unity.

Q = the flood discharge.

L = the width of the active portion of the channel.

q = the discharge per unit width $q = Q/L$.

I = the slope of the channel bed.

Qualitative analysis, as well as actual observation, shows that the tendency of turbid waters to sink is a function of the factor $f = q\ (d-1)$, and that the propagation of a density current along the depth of the reservoir is a function of f and of I, or $p = \phi\ (q,\ d-1,\ I)$ per unit width. The factor f expresses, in the form of a convenient coefficient, the quantity of solid material in suspension arriving in unit time per unit width. The function p expresses the transport energy of the density current per unit of bed width.

The larger f and p become, the greater is the tendency to plunge and to form a density current (Fig. 2). In arid regions, where, during floods, the parameter $d-1$ is large, density currents can transport fine particles as far as the dam.

In the course of propagation of a density current, any factor tending to reduce p (increase in L, reduction of I, abnormal roughness of the bed, a sharp bend, a ridge of deposit, etc.) results in a slackening of turbulence and in the deposit of particles. The factor $(d-1)$ thus diminishes, and it may be conceived that at a certain critical value the phenomenon may become very unstable and that the density current may little by little lose its transport energy, grow progressively weaker and finally disappear. We have formed such currents artificially in a natural reservoir by replacing mud in suspension (Fig. 3), but the current did not extend more than a few tens of metres because the term p had such a low value. On the other hand, any factor tending to increase p (increased slope, pick-up of particles from upstream deposits, etc.) increases turbulence and sometimes $(d-1)$. It is possible to obtain a chain reaction such as occurs with snow avalanches, which are density currents in which $(d-1)$ and I have very high values.

From this schematic analysis it can be seen that the conditions leading to the propagation of density currents in a given reservoir are very variable, and all generalisations must be avoided.

The analysis of the phenomena of plunging and of propagation is very difficult. The principal uncertainties are: (a) dilution, which interferes with plunging and the effect of which becomes more marked as the transport energy increases, and (b) the conditions at the interface or transition zone between the density current below and the clear water above.

When the plunging energy is weak, turbulence is weak and decantation commences immediately, and the density current may either progressively die out or take the form of an intermediate current if there is a temperature gradient in the reservoir. Such currents have a very low capacity for transport and are very unstable. They can be observed when the waters arriving in the reservoir are relatively lightly loaded (ends of floods, after-flows, discharge from melted snow).

In an arid region it is possible to detect in a single reservoir density currents at depth reaching the dam, currents at depth dying out rapidly, and intermediate currents. Evidently the velocities of these currents will be very variable. Thus, at the Iril-Emda dam, we have observed that if the prevailing velocities are in the region of 1 ft. per sec., velocities of considerably higher and lower values are also recorded. We have recorded velocities of 2, 3 and 4 ft. per sec. by submerged current meters. These velocities appear to be abnormally

Fig. 2. Plunging of turbid water on arrival in a reservoir. Note the accumulation of branches on the line of contact with the counter-current of clear water

high, as the actual records do not admit of a velocity regime much in advance of 1 ft. per sec. They can be explained by a fairly high density and a fairly steep bed slope (7 : 1000). But we are of the opinion that if more current meters were placed in reservoirs the conclusion would quickly be reached that the case of Iril-Emda is not unique.

These high velocities have enabled us to observe that density currents can erode unconsolidated silt deposited by previous currents having less energy. Probably this has been produced by a chain reaction analogous to the avalanche, cited above, but this is a hypothesis that could only be confirmed by observations at numerous points in the reservoir—observations that would be difficult and costly to carry out.

Added to the complexities of plunging and of current propagation is another disturbing factor—the accumulation of silt in the vicinity of the dam. When the head of the density current reaches the dam the turbid waters begin to accumulate, this action being accompanied to a greater or less extent by secondary phenomena such as wave reflection and eddies. The succeeding turbid waters thus encounter layers of water of a density practically equal to their own. The energy and the velocity diminish, and decantation of the largest particles is initiated. Subsequently, the layers nearest to the bottom reach a density higher than that of the current arriving from upstream, which tends to become an intermediate current of feeble energy (small density difference and small slope). By reason of the dilution of the density current the volume of turbid water accumulating at the bottom of the reservoir may be double that of the flood so that by the time the flood is expended, the silt accumulation may extend a great distance, and the coarser particles are deposited farther and farther upstream. Nevertheless, however severe the flood, there is a certain amount of turbulence at least in the region upstream of the accumulation. In those regions where this turbulence ceases, decantation proceeds at a speed depending on the size of the particles and the concentration. Flocculation may also occur to hasten the decantation.

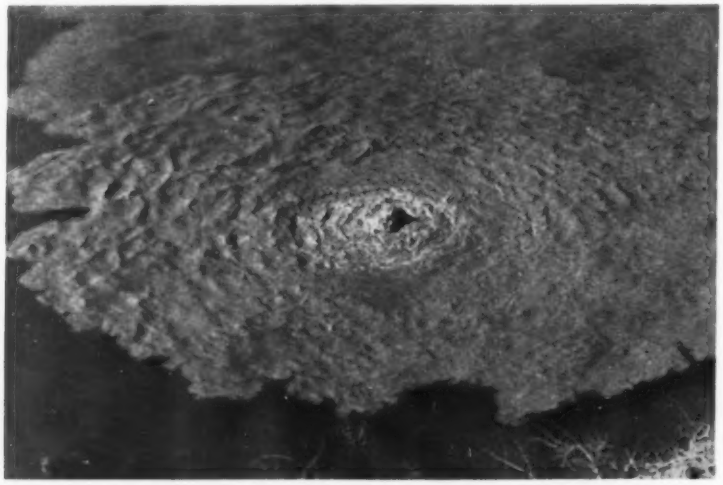


Fig. 3. Production of a density current by a mud emulsion. The plunging action can be seen at the top of the photograph

Fig. 4. Scour discharge of silt at Iril-Emda dam (density 1·060)

To the vertical component of the velocity of the particles must be added a horizontal velocity which is a function of the slope of the bottom of the reservoir. This is very important and merits detailed description:—

If a tank with an inclined floor be filled with turbid water, vertical decantation commences at all points. On the more elevated portions of the floor a tendency will develop for the water to become more heavily charged than that at the same level over the lower parts of the floor. Thus the lines of equal density are not horizontal. There is then a horizontal movement of the particles sufficient to overcome the rigidity of the silt as it begins to concentrate

In a reservoir some hours after a density current has ceased, the lines of equal density can be seen to be strictly horizontal. Some days later a fairly sharp separation is established between the clear water and the silt, with a slight slope towards the dam. This slope is created by the differences in thickness of the bed of mud in course of consolidation, the rigidity being too high to allow of horizontal sliding.

Such are the phenomena that are observed in the base of a reservoir in the complete absence of scouring. Later floods have the effect of tending to level off successive deposits towards the horizontal, and in reservoirs that have been in service for a good many years and where the silt has not been scoured, this is the reason why the degree of inclination of

the plane of separation between clear water and silt is very slight. Simultaneously with the piling up of the silt should be noticed an extension upstream of the accumulation, an enlargement of the channel section, and a diminution of the slope—all factors which tend towards more rapid decantation and quicker dissipation of energy.

Now let us suppose that when the density current reaches the dam we open one or more scour sluices. The horizontal component of the velocity of the particles will obviously be increased by that of the drainage velocity, and the higher the discharge of the scour sluices so much the greater will be the removal of particles. Also, if scouring is systematic, in other words if the slope of the bottom be maintained, the condition in the proximity of the dam will always remain the same.

But a dam is built primarily to conserve the water in the reservoir, and too great a loss of water at each flood cannot be entertained, so that it becomes necessary to adjust the sluice discharge and the density of the draw-off to the needs of water economy. We therefore determine what may be termed "the economic scour density," which expresses the amount of water consumed to avoid a given loss of reservoir capacity. The higher the scour density the less water will be consumed, but the more pronounced will be the "controlled slope," or the modification to the bed, on account of the greater rigidity of the deposit.

Having discussed these general considerations we

Fig. 5. A bay in Iril-Emda reservoir containing deposits that cannot be remobilised by natural flows but will be scoured by large-capacity waves

can now proceed to give a condensed description of the operations carried out at the Iril-Emda dam.

Draw-off at Iril-Emda Dam

The Iril-Emda dam regulates the waters of the Oued Agrioun to enable power to be produced in accordance with the requirements of the electrical system. It is about 200 ft. high and stores about 5,400 million cu. ft. The water passes through turbines at the foot of the dam and is then diverted by the small Kerrata dam to the Darguinah power station operating under a head of 1,200 ft.

The scour discharge from Iril-Emda (Fig. 4) is passed through the Darguinah turbines, so that the

Fig. 6. Oued-Fodda dam. Silt is being withdrawn in the foreground and water allowed to overflow in the rear. It is evidently more useful to scour the silt than to allow clear water to overflow

energy loss involved is not more than one-seventh of the total head.* This accounts for the low density of the draw-off (between 1·040 and 1·060). To avoid the frequent operation of the scour sluices at restricted opening, scouring is effected by small valves, 1 ft. 4 in. in diameter, bypassing the main scour sluices, and the discharge is regulated by altering the number of small valves opened. To facilitate observations offtakes have been installed at different levels in the reservoir, which enable the vertical density distribution at any moment to be determined. Further, the lowest offtake is permanently open, and a photo-electric cell gives warning of the approach of turbid water.

The dam has been in service since September, 1953, so that two years' observations are now available. The most important results are as follows:—

(a) Numerical results

Hydrological Year	Number of Scourings	Weight of Solid Particles Removed Tons	Type of Year
1953-4	13	1,000,000	wet
1954-5	25	600,000	dry
Probable annual mean		900,000	

* Experience at Iril-Emda is such as to guarantee that, thanks to systematic scouring, there is no further risk of the bottom sluices being obstructed by silt. Indeed, the intakes for the turbines could be situated at nearly the same depth as the scour sluices, or even placed with them. Such an arrangement will be adopted in the Serre Ponçon dam on the Durance (France). Draw-off is then made without loss of energy. There is even a gain of energy because of the weight of the solid particles, and this gain goes to compensate for the wear on the hydraulic equipment.

(b) Since the initial months of use the controlled slope of the deposits above the offtake established itself at 3 : 1000. This information gives an idea of the controlled slope necessary for draw-offs of densities between 1·040 and 1·060, and it is obvious that for higher densities the slope would be steeper.

(c) Scouring very rapidly became an operating routine, and the personnel have no reluctance to use the small valves. No incident has occurred during the two years, and, surprisingly, there has been no obstruction to the small valves.

(d) Capitalising the expense of the laboratory research, the cost of the installation, the maintenance of the sluices, and the loss or devalorisation of energy, the recovery of capacity represents an annual return of the order of 60 per cent. This very high return destroys any argument for economy in scouring.

(e) Scouring the Iril-Emda silt has resulted in evacuating 45 per cent. of the total solids arriving in the reservoir. Not all of the fine particles are evacuated because of after-flows and snow melts, of low turbidity, which deposit their solid material at the upstream end of the reservoir. But even so, the result is sufficiently remarkable to afford the hope that scouring in arid regions will become the general rule.

Draw-off at the Oued Fodda and Ghrib Dams

At the time of installing the scour sluice of the Oued Fodda dam and the flooding of the Ghrib reservoir (the rise of water level being controlled by the bottom sluices) the opportunity arose to make some observations which, although of short duration, were none the less interesting. It was shown that to open bottom sluices at intervals of about a year removed hardly 5 per cent. of the total solids, and this will not astonish the reader in view of what has been said above about the rigidity and the consolidation of the silt. But it so happened, both at Fodda and at Ghrib, that after we had loosened a mound of consolidated deposit, we had a heavy flood during which the solids were rapidly removed, the proportion of material evacuated being of the same order as that at Iril-Emda.

Fig. 7. Deltaic zone in Iril-Emda reservoir

Fig. 8. Detail of the deltaic zone seen in Fig. 7. The deposits that have not been picked up contain a large amount of clay

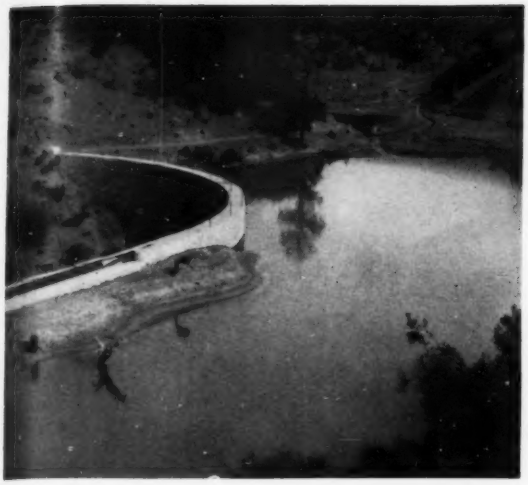


Fig. 9. El-Ouldja experimental reservoir

One conclusion is obvious—that when speaking of moving silt by scouring it is necessary, if one wishes to be objective, to define the age of the accumulation. It is because this factor of age is neglected that examples are quoted from time to time tending to prove that scouring has a very limited efficacy.

Approach Transport and Flotation Transport

Not all of the fine particles are carried as far as the dam, and the heaviest elements (sands and gravels) are deposited in the upstream section. Thus, although scouring reduces the speed of silting up of a reservoir, in order to ensure that the capacity is maintained permanently it is necessary to resort to other procedures. Following observations on the grain analysis of deposits and on their consolidation and remobilisation characteristics, we considered from the outset the possibility of inducing artificial density currents to pick up the fine deposits (tests with a water/compressed-air emulsion). These investigations showed that the simplest and most economical method consisted in transforming the weak continuous flows arriving in the reservoir into large-capacity scouring waves, which, when the water level is sufficiently low, effectively remobilise the deposits, become heavily charged with fine particles, and on arriving at the water surface descend in the form of a density current carrying the fine particles up to the dam, where they can be removed by scouring. At the same time the heavier particles are carried farther downstream than they would have been without this wave action. It is for this reason that this technique is called "approach transport." A small dam has to be built upstream and as near as possible to the reservoir, fitted with large quick-opening sluices. Except for peak flood periods, all flows are transformed into waves. In addition to the increase in the quantity of material removed by scouring, the reduction in evaporation by the elimination of clayey deposits and the suppression of the risk of marsh formation should also be taken into account. It is hoped that at Iril-Emda this procedure will enable the proportion of material removed by scouring to be raised from 45 to at least 60 per cent. (Figs. 5, 7 and 8).

The removal of the heaviest materials can be effected by waves only if the reservoir is previously empty. In arid regions, to empty a reservoir is to risk a shortage of water at a time of demand, due to the

Fig. 10. Kerrata diversion dam

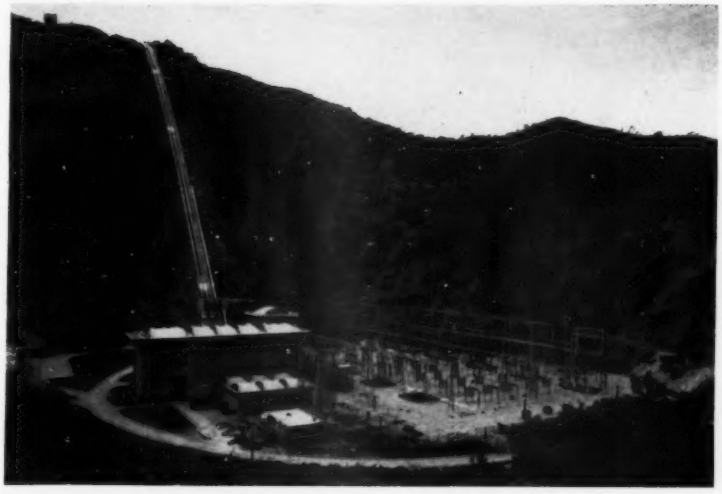


Fig. 11. Darguinah power station, surface arrangements

Fig. 12. Darguinah underground machine hall

caprices of the weather. Thus, this procedure can only be adopted if the hydro-electric development has hydraulic connections sufficient to guarantee the load and to supply the scour dam with sufficient water to break up the heavy material. In the Oued Agrioun development the diversion of a neighbouring stream, the Bou-Sellam, with a regulating dam, will enable the technique of approach transport to be completed by that of "flotation transport." The more the approach-transport technique has been applied, the more rapid will be the evacuation of material by flotation transport, and the less will be the water needed. It is expected, in fact, that before the reservoir has been completely emptied, practically all the material will have accumulated near the discharge sluices.

The factors underlying these techniques are such that precise calculations cannot be made, and before applying them to Iril-Emda and isolating the principal parameters, tests are being carried out on the small experimental dam of El-Ouldja (Fig. 9), which has already been most useful for the statistical study of solid transport and for trials with scouring. The first results show that the remobilisation of the fine particles induces waves of density currents which enable scouring to be more effective than was first expected. The larger materials move progressively over the upstream mound of deposit, which, before the tests, had created a solid ridge three times as long as the original backwater. Several years of research would be needed for a full study of the phenomena involved, but already investigations are being made on a scour dam on one of the arms of the Iril-Emda reservoir.

It is clear that flotation transport cannot conserve the original reservoir capacity in its entirety because of the coves and little creeks that will not be completely cleared, but an indefinitely maintained capacity will be reached the proportion of which will vary with the size analysis of the materials and the topography of the reservoir. It is hoped that at Iril-Emda this proportion will reach at least 80 per cent., and the importance of this will be appreciated when it is stated that in the absence of any system of evacuating the sediment, 50 per cent. of the capacity would be lost in about 40 years.

Conclusions

The case of Iril-Emda proves that sedimentation in reservoirs can be successfully controlled, and it is to be hoped that this case will not remain unique. In order to render the needful information available to engineers, Electricité et Gaz d'Algérie has published *"Compte Rendu No. 2 sur la Lutte contre la Sédimentation des Barrages Réservoirs"* ("Report No. 2 on the Fight against Sedimentation in Dammed Reservoirs." Text is in French only). This report contains fuller numerical data than it is possible to embody in the present article and also includes some further chapters. Those interested in these questions and desirous of obtaining a copy of this report should write to Electricité et Gaz d'Algérie, 2 Boulevard du Télemly, Algiers, and a free copy will gladly be sent within the limits of the stock available.

Società Italiana per Condotte d'Acqua, Roma. We have been pleased to receive an elegant brochure published by these well-known manufacturers of water conduits on the occasion of the 75th Anniversary of their foundation. The chapter devoted to Large Canals and Hydro-electric Plants (pp. 61 to 90) is of special interest, containing as it does an abundantly illustrated description of some of the most up-to-date Italian developments. The photographs of the Val Gallina and Flumendosa dams, and of the Premadio plant, are particularly impressive.

A New Approach to Tidal Power

Percy H. Thomas suggests an approach to tidal-power projects, based on a special design of waterwheel, which is claimed to offer a greatly increased output. Figures are given for the Passamaquoddy Bay project

IN view of the recent news items on the tidal-power project undertaken by Electricité de France near St. Malo in Brittany, and of the studies made some years ago of the Severn Barrage, the readers of WATER POWER will be interested in a new approach to the exploitation of tidal power, utilised by the writer in the studies of the well-known Passamaquoddy Bay project. This new approach is based upon a new type of waterwheel, called the impact waterwheel (I.W.W.),

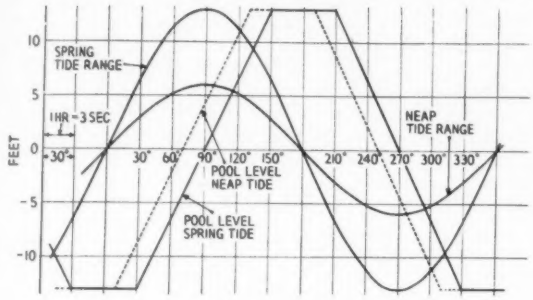


Fig. 1. Diagram of tide flows

conceived by the writer in connection with his extensive researches on the wind turbine. The performance characteristics of the I.W.W. permit operation interchangeably as a pump or a turbine, and also operation with the flow in either direction, with a change of blade pitch, all with the same direction of rotation. Further, the I.W.W. operates normally at constant speed even when the hydraulic head drops to very low values, of course with a lowering of output and efficiency.

This performance enables an extraordinary increase in output in any particular tidal project over that of the usual high-pool/low-pool operation. For example, according to studies made in the case of Passamaquoddy Bay, taking the international project, instead of two pools, one of about 101 sq. miles and the other about 27 sq. miles, a single pool of 128 sq. miles may be utilised, nearly four times the area of the ruling 27 sq. miles smaller pool of the two-pool plan. Further, the I.W.W. enables the wide variations of the available energies between the spring and neap tides to be materially reduced by pumping from the ocean, on all but the spring tides, to fill the pool to spring-tide level. After holding the pool full until the tide has dropped to the optimum level, the full pool is discharged through the wheels. As the pumping is done at the flood tide, which lingers for some time, there is a gain of several fold in the pumped water when discharged. A similar operation at the ebb tide enables the pool to be emptied to the spring-tide low at other tides, with a corresponding gain of power on filling. At extreme neap tide the natural energy available at Passamaquoddy is only 21·5% of that at full spring tide, the energy being proportional to the square of the range, but with this pumping the neap energy is raised to 43·5% of the spring energy, giving an average for all tides of roughly 70%.

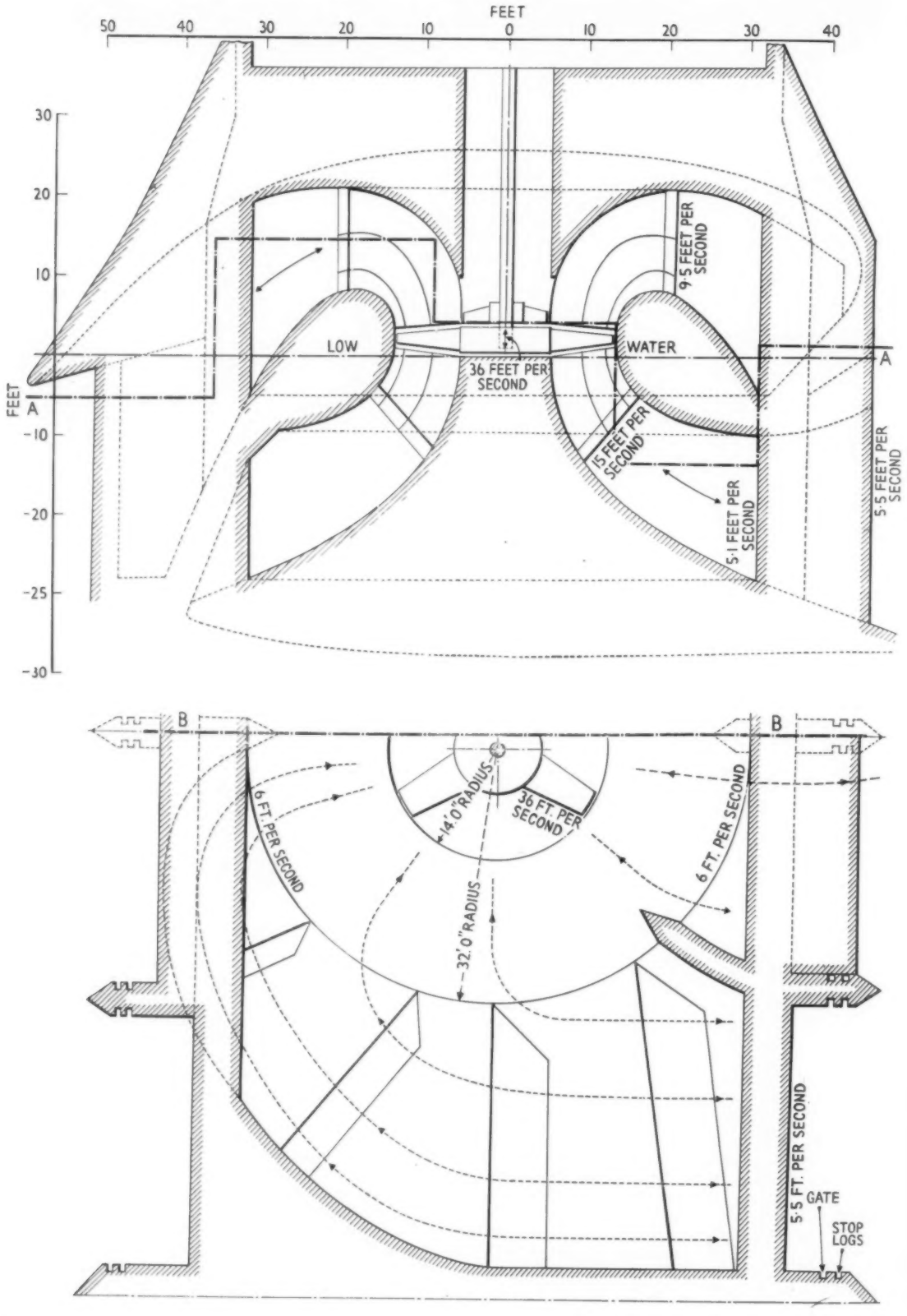
The Impact Waterwheel

Before giving some further consideration to this tidal operation, some additional information will be given on the I.W.W. This wheel has little in common with conventional turbines, but is related to the airplane propeller, the wind turbine and the hydraulic ram, as all three have the intermittent impact feature which definitely distinguishes them from conventional turbines. Further, neither the wind wheel nor the I.W.W. has a swirl or vortex, this resulting from the fact that their blades are isolated from one another by open spaces, this feature being inherent in the intermitent impact. Nevertheless, in physical form, the I.W.W. closely resembles the wheel of the Kaplan turbine, taken by itself, omitting the scrollcase and wicket gates. The I.W.W. has the enlarged hub and two or three narrow blades, and is located at a narrow throat in the streamline flow channel between the approach and the draft tube. The water stream would be a spouting jet through the throat except for the rapidly rotating blades, which, working through the inertia of the water, force the flow to take the velocity corresponding to the average pitch. Since the blades hold back the flow they carry the whole penstock pressure, and since they have a pitch, there is a component of this pressure in the direction of blade rotation, which constitutes the torque force of the wheel. Thus the action of the I.W.W. has much in common with that of a ship's screw; the airplane propeller has often been called an "air screw." It may be added that the I.W.W. has a rotational speed two or three times that of the Kaplan wheel—a characteristic that is very favourable to the generator, especially with low heads.

The writer has a U.S. patent on the I.W.W. However, as none has so far been tested, a prototype must be built in advance of any undertaking. The performance of known waterwheels and wind wheels, the numerous scientific researches on the subject, and the parallel character of the laws of aerodynamics and hydrodynamics make the operation of the I.W.W. clear.

Pattern of Operation

On looking further into the matter of tidal-power projects, certain hurdles appear. For example, in order to secure the maximum output, the wheels must be operated only while the head between the tide and the pool is most favourable. In studies on Passamaquoddy the writer concluded that the optimum output was obtained by operation for a three-hour period with idle-


FEET
50 40 30 20 10 0 10 20 30 40
30
20
10
FEET
A
-10
-20
-25
-30
LOW
WATER
A
36 FEET PER SECOND
9·5 FEET PER SECOND
15 FEET PER SECOND
5·1 FEET PER SECOND
5·5 FEET PER SECOND
B
B
6 FT. PER SECOND
14'0" RADIUS
36 FT. PER SECOND
6 FT. PER SECOND
32'0" RADIUS
5·5 FT. PER SECOND
GATE
STOP LOGS

ness for the following period, and that the pattern on the inward flow should be a duplicate of that of the outward. This series of three-hour blocks of generation followed by three hours of idleness presents a problem of equalisation to secure firm power, quite different from that of equalising the spring-tide/neap-tide changes.

With the pattern of operation so established it is appropriate to indicate a convenient method of computation for the rather complex total of output. Referring to Fig. 1, assume that the tide level follows a sine curve, shown on the chart for the spring tide as above and below the mean tide level. A similar sine curve is shown for the neap tide. The range of these tides shown is that used in the Passamaquoddy study, 26 ft. for the spring, and 12 ft. for the neap. To indicate the pool level an oblique straight line was found favourable, as representing a constant volume of flow. Such lines are shown on the chart. It is assumed that the area of the pool represented is such that the extraction of one cubic foot of water will lower the pool level by one foot, the pool having been assumed to have vertical sides over the operating range. The change in ordinates then measures the flow for any period. The chart has also been given an arbitrary time scale of one second for every 10° of rotation of the tide-cycle vector, giving 18 sec. for a half tide. The energy in the wheels is then measured by the product of the flow for one second times the average difference in head between the pool and the tide for the second, this energy being in arbitrary units fitting the chart. The energy for a half tide is the sum of these second energies for 18 sec., half of these being idle. During the portion of the half filling cycle where the pool level is above the ocean level, and during the portion of the emptying cycle where it is below the ocean, the action is pumping.

The sum of these second energies for one typical half cycle for the spring tide was found to be 285·3 − 10 (pumping) = 275·3 arbitrary units on the chart. For the neap tide it was 147·4 − 27·4 = 120 units, average 197·6 units. To get the energy in kW-sec., multiply by 64 (the weight of a cu. ft. of sea water) and divide by 738 (ft. lb. per kW) × 18 (sec.) = 0·95 kW average for the half cycle. The average per cu. ft. of water is 0·95/19 (the cu. ft. of water used on the chart in the half cycle) = 0·05 kW. The time-scale ratio for the actual half tide is 6 × 3600/18 = 1,200, so that the actual kW for any case will be 0·05 times the total number of displaceable cu. ft. of water in the pool, divided by 1,200. For a pool of 25 sq. miles area the average power comes to 552,000 kW.

The hurdle of the equalisation of the three-hour blocks may now be considered. The additional generating capacity required is equal to the average capacity and the total installed is double. Assuming that this three-hour gap will be bridged by pumped-storage, there must in all be three times the average before 24-hour firm power is obtained—3,000 kW for an average of 1,000 kW of firm power. No feasible smoothing out of the square blocks of power would reduce the total materially. Fortunately the generating units utilising the I.W.W. are very low cost, and in any case do not stand very large taken per kW.

Fig. 2 (opposite). Sketch of Thomas Polygon Cone Draft Tube

NOTES: (a) The plan shows the upper scroll chamber up to a radius of 32 ft. and the lower scroll chamber beyond it; (b) the guide plates, seen in the elevation, are omitted in the plan for the sake of clarity.

Draft-Tube Design

In these tidal plants the draft tube presents another hurdle, for there must be an entrance and an exit on both sides of the dam, and on account of the relation of the kinematic energy of the water stream to the total wheel power (up to 100% in many cases), and the necessity for the highest feasible efficiency on account of the low head, entrance and exit water should be at very low velocity. Further, it is convenient to locate the setting on top of the dam. For these reasons the writer has devised the Polygon Cone Draft Tube (patented in the U.S.A.), which is a modification of the well known Moody draft tube, bell shaped, but in this case fabricated as a twelve sided polygon, to facilitate construction, transportation and to eliminate vibration from the water stream. A typical setting is shown in the sketches, Fig. 2. It is believed that the volume occupied by this setting is appreciably less than half any design based upon the usual elbow type. This design shows a reduction of the stream velocity of the wheel discharge up to six to one. It should be explained that the three parallel curved subdivisions of the draft tube leading from the wheel are so proportioned as to width, length and taper that the stream entering with a constant velocity at all passages, emerges with all the substreams at the same velocity and in the same direction, so that they may merge without turbulence. The ratio of the radius and thickness of the subpassage should be conservative.

The actual volume of storage required for equalising the three-hour blocks is naturally very small, only three hours for the average output. For an output of 1,000 MW this would be 3,000 MWh. In a pumped-storage with 250 ft. head and 10% drawdown this requires only about one sq. mile of reservoir area. On the other hand, equalising the spring-tide/neap-tide variations, as estimated for Passamaquoddy from the curves, requires a reservoir for only about 2½ days' output. The generating capacity to be added to the average is about 4/10 thereof, and the generating capacity already provided above for the three-hour storage is available and ample for this service. When so equalised, as stated above, the long-time average power is 70% of the spring-tide maximum.

Spring-Neap Equalisation

Ways and means for securing this spring-tide/neap-tide equalising storage must depend upon the conditions of each case, but where there is a sufficient amount of seasonal reservoir capacity in the general network into which the tidal power is to be delivered, this storage can provide the equalisation with great economy, for the net effect upon the seasonal reservoirs is an elevation of level for a week followed by an equal depression for a week, leaving the seasonal storage unchanged at the end of that time. There is more to be said on this suggestion, but this is not the place. The increase of line loss in transmitting the pulsating power to the network at 70%, would be only of the order of one-tenth of the loss.

It may be pointed out that where it is feasible to use pumping to raise the level of the pool above the spring-tide level, a corresponding gain in output should be possible.

(Continued on page 193)

Fig. 8. The longest bulk freighter on the Upper Lakes, s.s. "T. B. McLagan," 715 ft. overall, passing Detroit

The St. Lawrence Seaway and Power Project

In our last issue H. G. Cochrane, M.E.I.C., described the physical aspects of the St. Lawrence Seaway and Power Project, with particular emphasis on power development. In the following article, navigation aspects are dealt with and the effects of both power and navigation on the Canadian and U.S. economies are discussed

PART TWO

DUE for completion by 1959 or 1960, the first, and possibly the greatest, economic impact from the Seaway, as far as Ontario and the New England States are concerned, will come in 1958, when first units of the power plant go on the line. The 2·2 million h.p. to be harnessed in the International Section is the largest block of cheap hydro power still available to areas adjacent to the St. Lawrence valley. Half belongs to Ontario, half to New York State. Present estimated cost (assuming outlays by the two countries are pooled and divided equally), is about $280 per installed h.p. at the busbar. Compared with this, energy from hydro power recently developed in the Niagara area costs almost twice as much to produce per kilowatt-hour.

This power will be needed early in 1957. By that time the output of Ontario's Sir Adam Beck No. 2 will be fully absorbed, and Seaway power is expected to take care of the growth in Hydro's Southern Ontario system until 1963. After that Ontario must rely on new thermal plants, the power from which will likely cost 2½ to 3 times as much as Seaway power. New York and New England States, though not yet actually short of power (they recently built a number of large thermal plants) will also have a ready market for their share. Power costs in these States are higher than in the rest of U.S. Cheap energy from this new source can do much to encourage new industries, and the opening up of undeveloped mineral resources in Northern New York.

Cheap Power the Stimulant to Central Provinces

Over the past decade every $1 spent for power development in Canada has been followed by an annual increase of about $4·50 in manufacturing production. Distribution of Ontario's share of 1·1 million h.p., therefore, could well bring an annual factory production increase of nearly half a billion dollars (some 2½%). Similar growth could accrue to New York and part of the New England States. More expensive energy from alternative hydro sites or thermal plants would not have been as attractive for heavy industries as will cheap Seaway Power. Quebec, though it too will benefit ultimately from the further 1·2 million h.p.

in the Lachine section, has other large sites under development which will be adequate until 1960. Moreover, completion of Lachine power facilities are not essential for completion of the navigation channel, as is the case in the International Section further upstream.

Eastern Ontario, from the Quebec border up to Kingston, has high hopes of an industrial boom all along the Seaway waterfront. While construction is under way this area should certainly enjoy prosperity. A permanent or long-term boom is problematical, as this apparently has little geographical advantage over other Ontario areas fronting on the Great Lakes and served by the Southern Ontario power system. All sources of power are pooled within that system and no reservation of cheap St. Lawrence power or any preferential rates for Eastern Ontario areas will be considered.

Cheap power, rather than cheap water transportation, is the dividend Southern Ontario is counting on. Industry will get cheap water haul for exports like automobiles, meat, implements, farm products, lumber and paper, imported British Columbia lumber, American coal and many foreign items. What really counts, though, is assurance of another 1 million low-cost horse-power to maintain the province's industrial growth for another decade.

Seaway power can be produced at half the cost of that now being developed at the Sir Adam Beck No. 2 station. By getting Seaway power now instead of having to build more steam, gas-turbine or atomic power plants, power consumers will save about $30 million a year, Hydro officials say. Ninety per cent. of Ontario's industry depends on electric power; two-thirds of the Hydro's output is bought by industry. Higher power rates would affect consumers—prices of practically every product made in the province would go up.

Effects of Navigation

While benefits accruing from the development of Seaway power are largely taken for granted, particularly in Ontario, Quebec and the New England States, benefits to be derived from the opening up of deep-draft navigation into the Great Lakes are less easy to visualise and to assess. However, completion of navigation features, due by the spring of 1959, will no doubt bring about a far-reaching but gradual economic revolution for the eastern half of the continent. U.S. Atlantic and Gulf ports will probably be hurt, and the current trend of steel industries moving to the Atlantic Seaboard States retarded at the expense of those States. On the other hand, traffic in and out of the Great Lakes ports will be stimulated.

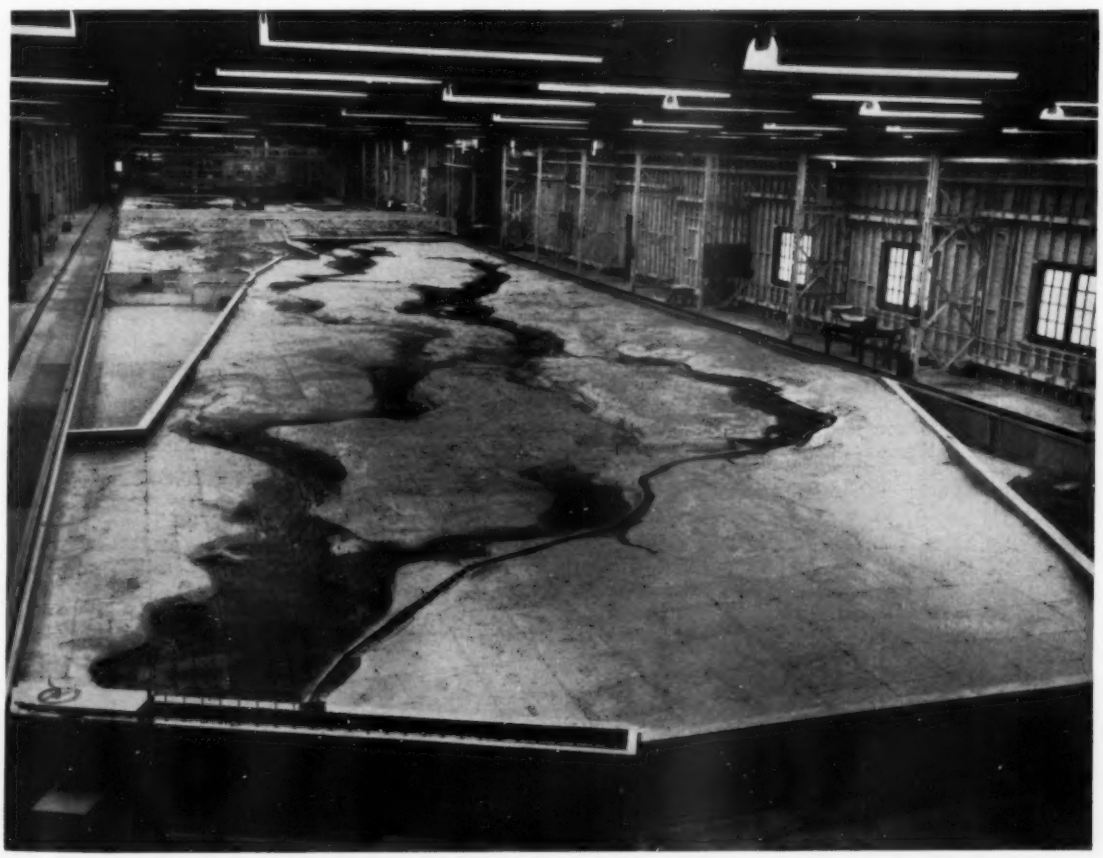


Fig. 9. St. Lawrence Model No. 3 of the dewatering and closure area, International Rapids Section, at Ontario Hydro's A. W. Manby Service Centre. Models Nos. 1 and 2 are in the far background

Fig. 10. Access tunnels to the power-house site under the Cornwall Canal

Lewis G. Castle, Administrator, U.S. St. Lawrence Seaway Development Corporation, in an address last year at Watertown N.Y., drew attention to the Seaway's place within the vast network of waterways, which included the Calumet-Sag Channel to be commenced this year, connecting it with the entire Mississippi Valley system, which in turn connects with the 1,100-mile Gulf Intracoastal Waterway. Thus a great trunk line of water navigation from the Mexican border and Florida would reach up through the centre of the continent as far as the Appalachians and up the Missouri almost to the Rockies. He foresaw a major reorientation of the nation's business geography. In place of the main currents of commerce following east-west rail lines, northern states hitherto left in the backwaters of trade would find themselves squarely in the main current. Since prewar, he said, the proportion of ton mileage traffic carried by water had risen from 2 per cent. to 17 per cent. in 1953, and was still accelerating.

But, he cautioned, the investment of nearly a billion dollars in construction in the St. Lawrence Valley was bound to cause some kind of a business boom and distortion. Unless at the end of the construction period new industries were ready to take up the payrolls in equivalent amount, a business let-down might follow. But these adjustments would be short range. He expressed no doubt that in the long run the permanent build-up of the region would far outreach the temporary boom of the construction period.

In Canada scarcely a dissentient voice is heard. Ungava's iron-ore fields and western wheat provinces will be first to gain from cheap transportation. The St. Lawrence valley and the whole Great Lakes area will benefit from cheaper shipping rates for export and imports and the resulting stimulus to industry. Even the remote Maritime provinces and Newfoundland will be brought closer to mid-west markets. The Seaway will create an upheaval in transportation and trade patterns that will touch every Canadian pocketbook. Canada, as a whole, has nothing to lose!

Harbour Development on Great Lakes

Great Lakes ports on the U.S. side are not letting the grass grow under their feet. Many of these cities have already set up Seaway Committees. As an example, Cleveland is planning a $25 million Trade Mart, similar to the one in New Orleans. The city proposes to build a $15 million breakwall along the entire waterfront to serve as an erosion barrier, and to provide additional berthing space for lake and ocean vessels plying the Seaway. Cleveland is also boosting for a World's Fair in that city to coincide with the opening of the Seaway.

The Hon. Alexander Wiley, speaking before the U.S. Senate last year, reported that the Chicago Regional Port Authority would commence a $22½ million project of harbour and terminal improvement at once. Milwaukee plans a $4-7 million harbour improvement. Buffalo will spend $2-3 million on deepening its harbour. Ashtabula will spend $5 million on its harbour. Manitowoc and Erie are considering port development. Besides this there are $109 million worth of Federal channel improvements under way or planned in the Upper Great Lakes. One U.S. army engineer, he said, estimated that at least $500 million might be invested in the Great Lakes area in the next 10 years by federal, state, city and private agencies for harbour and channel improvements.

The Toledo Port Authority plans a $20 million waterfront industrial district on Maumee Bay, with bulkheads for 30 slips. In Indiana a $60 million seaport on Lake Michigan between Michigan City and Gary, to be built with private capital, was declared legally feasible by an adviser to Governor Craig. After the port is built the State Board of Harbours and Terminals would acquire the facilities, while the federal government would build a breakwater and dredge the harbour.

Canadian ports are planning too. Sept Isles seeks an all-year ocean port. Quebec will improve its elevators and cold storage and dredge St. Charles Estuary. Trois Rivières proposes more wharf space, sidings and sheds. Montreal is getting a 10,700 sq. ft. transit shed from the Harbours Board. Kingston will spend $4 million on dredging and construction. Toronto is opening a new marine terminal and will add 3,300 ft. of docks. Hamilton extended its docks and terminal buildings last summer. Windsor is spending $3 million on dock facilities.

Advice on Existing Ports

Speakers at the joint convention of the American Society of Planning Officials and the Community Planning Association of Canada, meeting at Montreal last September, heard H. C. Brockel, municipal port director of Milwaukee, discuss planning in relation to the Seaway. "Before Great Lakes ports can assume the stature of salt-water terminals," he warned, "they must offer the services and facilities that ocean operators have been accustomed to for centuries. These ports will need deep-draft channels and anchorages, modern port facilities, adequate terminal handling equipment, warehousing and storage, rail and truck access to their waterfronts and good lines of communication to the interior," he continued. "An adequate supply of longshore labour must be on hand when the first ship arrives. The peak seasonal supply of waterfront labour must be absorbed in the community during winter months, or will require community support through social services."

In planning their future ports, the speaker urged lake officials to make some public agency responsible for port affairs, be it port authority or its equivalent. He advocated protection of waterfront areas by intelligent zoning, and a reasonable, realistic and economic balance between parkway, port and recreational needs. It was no coincidence, he pointed out, that only three representative public port developments had made progress in the entire Great Lakes basin. These were Toronto, Hamilton and Milwaukee, cities which long ago created port bodies to develop and plan their ports aggressively.

Dr. Harold B. Mayer, who was engaged by the province of Manitoba to study the economic impact of the Seaway on that province, says that the general cargo terminals at Lakehead ports will be inadequate to handle increased traffic resulting from the Seaway. Built many years ago, they are not designed for handling cargo from modern ocean vessels that load and discharge through vertical hatches, requiring larger shoreward areas and modern sheds, heavy floor-load capacities, wide wharf cars and trucks. Better coordination is also needed, he points out, between Fort William and Port Arthur, and better planning for future development. The highway system from Lakehead to Winnipeg needs improvement for heavy truck traffic.

Ungava Ore the Key

The significance of Seaway navigation for Ungava iron ore makes the headlines today. Current shipments (8·5 million tons a year) go mostly by sea to the U.S. North Atlantic ports for trans-shipment by rail to the Pittsburg area. Smaller amounts are trans-shipped at Contrecoeur near Montreal to rail haul by N.Y.C. with similar destinations, and further small water shipments up-lake through 14 ft. canals.

With the Seaway open, after paying any likely level of tolls, Ungava ore will compete in virtually the entire Great Lakes market, otherwise largely out of economic reach. Immediate sale is seen for at least 20 million tons a year and growing markets thereafter. Mesabi low-grade and taconite ores will cost an additional $2 and upwards per ton within a few years, yet an expanding U.S. economy will continue to support the market for them.

U.S. steel mills will be consuming upwards of 100 million tons of ore in the near future. Thus these mills have faced an increased yearly cost of some $200 million which would mean even greater increase in end product prices. The Seaway will change all this, for with it Ungava ore can compete at present Mesabi prices, and much of the saving will be passed on to ultimate consumers.

Fig. 11. Excavation for the power house seen from the Canadian side in October 1955

Six Cents Saved Per Bushel

Addressing the Winnipeg Chamber of Commerce in the early part of 1952, Canadian Seaway President Lionel Chevrier, who was

Fig. 12. Dredges, each of 6 cu. yard capacity, at work near Spencer Island

then Federal Minister of Transport, said:

" No doubt you in Winnipeg and the west are concerned most directly with the benefits relating to the grain movement. The Seaway promises at least two benefits. One is a substantial saving in the cost of marketing grain. The other is an end to the shortages of lake shipping that have occurred in the past to hinder the flow to market. Both mean more dollars in the farmer's pocket. If the large vessels can carry the wheat the whole 1,200 miles to Montreal, the total water freight would not be more than 11 cents a bushel instead of (the present) 16 cents, not counting the saving in trans-shipment charges of not less than another cent a bushel. (The Dakotas, Minnesota, Kansas, Ohio, etc.,would be similarly affected.)

" But the savings promise to be even greater than that, thanks to the upbound movement of iron ore in sight. Carriers delivering ore from Sept Isles to Lake Erie ports would find it of advantage to pick up grain delivered to Port Colborne, say, or better still they could proceed to Lakehead to pick up grain for Montreal or beyond. Since upbound cargoes promise to outweigh the downbound—just the opposite of today—competition for these downbound cargoes should lower the rates and give western farmers the greater part of the benefit from the additional economy."

Rails Lose Some Freight But Gain More

Few transportation economists visualise the railways as being adversely affected on balance by diversions of freight to the Seaway. Almost half the expected Seaway traffic is iron-ore traffic, now non-existent. Another large portion already moves by water either passing from the Lakes to U.S. water routes or by trans-shipment to small " canallers," or going all the way by " canallers." Such traffic as the rails lose will be mostly items now paying little because of sharp competition from existing water services.

Continued Seaway-stimulated industrial development may well bring new high-rate traffic to the railways in some areas where low-rate tonnage may fall off.

Indeed, expanded rail facilities may be needed. Undoubtedly Seaway power and navigation will promote industrial expansion. That is the answer to railways, ports, power interests and others who have opposed the Seaway through fear of damage to themselves.

Traffic Potential

Few doubt that ultimately the Seaway will carry a vast volume of traffic, but opinions vary as to how much. Early in 1953, Canada's Transport Department economists came out with an estimate of 44·5 million tons a year. Of this total 18 million tons, they claimed, would be downbound traffic, and would include 10 million tons of grain, 3 million coal, 1·5 million iron and steel. Upbound traffic was estimated at 26·5 million tons, including 20 million iron ore. This estimate of 44·5 million tons has more recently been revised downwards to 31 million. SLSDC officials think 36½ million tons is a more realistic total.

These traffic estimates, of course, only relate to traffic through the Welland and the new canals to be built between Lake Ontario and Montreal. By comparison, tonnage carried on the Great Lakes by

American and Canadian inland fleets combined was close to 200 million in 1953.

Lakers Can Go Down-River

Few ocean vessels, it is said, will pass beyond Montreal. These ships, built for heavy seas, are short, deep, with centrally placed engines. Lake vessels are longer, with engines in the stern, crew quarters in the bow, leaving more cargo room amidships. Almost all the "lakers" being built today are of 25,000 tons capacity (average ocean freighter capacity is 10,000 tons). Lakers carry 800,000 bushels, ocean freighters only 350,000. It is therefore believed that lakers will handle practically all ore traffic to Lake Erie ports. Indeed economists predict that the Seaway's most important role will be to make it possible for lakers to go down-river, rather than to allow ocean ships to enter the lakes. There is no physical barrier to ocean vessels entering the lakes, but lakers' ability to handle traffic faster and more cheaply will give them an edge over seagoing ships.

But Canadian shipowners, says T. R. McLagan, president of Canada Steamship Lines, fear that U.S. and foreign-flag shipping may capture nearly all the Seaway trade unless changes are made in Canada's shipping laws. Access to the Seaway from overseas ports is open to all. Foreign ships are not permitted to carry cargo between one Canadian port and another, but British ships may do so. This places Canadian ships at a disadvantage, points out McLagan. A British sailor earns $80 a month, a Canadian $200. This traffic, shipowners argue, should be restricted to Canadian-built and Canadian-registered ships. They are also urging a Canada-U.S. treaty which would restrict trans-boundary trade within the Great Lakes to U.S. and Canadian shipping.

Coastal Trade Commission

The Royal Commission, set up last year to study Canada's coastal trade and to recommend whether changes in legislation are called for, have been holding hearings all across Canada. Submissions either (1) criticise Canada's Cabotage Treaty with Britain, which permits British flag vessels to carry cargo between Canadian Ports, requesting its repeal, or (2) argue strongly against any change in existing legislation. Amongst those of the former group asking protection for Canadian-built and operated vessels were shipping owners, shipyards, the principal labour groups, the railways, as well as chambers of commerce and a number of industries. Supporting the view that no change in shipping regulations should be made were the Shipbuilders Conference of the United Kingdom, who pointed out that Canada would face a comparable restriction in her U.K. export trade if British ships were pushed out of Canadian coastal trade, while the Dominion Marine Association, chief voice for the $200 million Great Lakes shipping fleet, withdrew support from proposed restrictions against British shipping on Canada's eastern seaboard, but continued to ask for restricting to Canadian ships the traffic between Canadian ports in the Great Lakes St. Lawrence area. They advocated a treaty between Canada and the United States to bar vessels of other nations from trade between the two countries in the lake-river region.

Gains For Quebec, Ontario and Prairies

Quebec City, Trois Rivières and Montreal, which used to oppose the Seaway in the belief that ocean shipping would bypass their harbours, have now changed their minds. Though some ocean vessels which now trans-ship at Montreal will proceed up-lake without stopping, lakers carrying ore will handle return cargoes cheaply because of competition. This will result in greatly increased trans-shipment at these ports, particularly Montreal.

Deepening the Hudson river in 1931 meant that 85 per cent. of ocean shipping could bypass New York to unload 140 miles further up at Albany; but this has not hurt New York as a port, point out Montreal shipping people. Albany is still a minor seaport, New York's harbour tonnage has tripled; so why should the Seaway divert Montreal's traffic to Great Lake ports?

Fig. 17. Looking downstream at permanent bridge between Barnhard Island and the U.S. mainland

Biggest Ontario market for raw materials and finished retail goods lies within a 50-mile radius of either Toronto or Hamilton. Ocean vessels of foreign registry unable to get full return cargoes here (being barred by law from coastal trading), will mostly return empty to Montreal for loading. Even those with part cargoes for farther up the lakes will probably unload at Hamilton or Toronto, rather than face an uneconomical trip farther west and the stiff competition from lakers on return grain cargoes out of Fort William. This means that Hamilton and Toronto will expand greatly as distribution centres. Toronto and Hamilton, however, will not get a monopoly on Seaway traffic.

Prairie farmers will benefit from the six-per-cent per bushel saving on grain shipped to Montreal and the earlier marketing made possible by Seaway navigation. Winni-

peg, and indirectly the eastern half of the prairie provinces, too, stand to gain from lower freight rates on the commodities shipped by water and rail from overseas, Eastern Canada and B.C.

Today the bulk of the central provinces' freight moving to the prairies—e.g., farm produce, and hard goods like refrigerators, stoves, automobiles and farm implements—goes by rail or by boat-and-rail to Winnipeg for distribution. Similar products from the central provinces to British Columbia take the Panama route as do European goods, instread of crossing the continent by rail. Completion of the Seaway will likely bring much of the distribution business back to Winnipeg at Vancouver's expense, thereby passing on freight savings to consumers in Manitoba and eastern Saskatchewan.

Little Advantage to Maritimes

Newfoundland and the Ungava area will probably be stimulated more than any part of Canada by the opening of Seaway navigation. Seven Islands will become Canada's number one port in respect to tonnage handled, paying off with more employment and a sharp growth in population with all that this implies. Labour for the ore fields will be found as far as possible in Newfoundland and the Maritimes. Royalties on iron ore will be a major source of new revenue for both Newfoundland and Quebec.

The effect of Seaway navigation on Nova Scotia, New Brunswick and Prince Edward Island is more difficult to analyse. Maritime coal will not benefit. Its most westerly market is Montreal and it needs a freight subsidy even that far. Downbound U.S. coal as return cargo may cut into its existing market. New Brunswick's potato harvest is too late in the season to benefit before winter closes navigation. But Maritime and Montreal sugar companies will be able to get West Indies raw sugar by Seaway if they move their refineries nearer their main market in Ontario.

Saint John and Halifax will likely get less grain traffic. The western crop will move out faster by Seaway, leaving a smaller winter movement by rail to Maritime ports. On the other hand these ports handle mostly winter freight during months when the Seaway will be closed. Their general cargo continues yearround and will not be reduced. Besides this, many Maritime products, such as pulpwood, paper, lumber and steel, which now move by rail to central Canada, will be able to move by water at savings of several dollars per ton.

British Columbia Will Not Be Hurt

In an address at Vancouver last fall, Seaway president Lionel Chevrier commented on the probable effects of the Seaway on British Columbia's economy. He did not believe that the B.C. fishing industry would benefit directly, although industrial developments in the Montreal-Toronto area would increase the market for canned fish. Regarding the fruit industry, most rail shipments of B.C. apples terminate in the prairie provinces and Ontario. The proportion that goes to Quebec might reap some benefit, although through rail shipments are more likely. Large east-west movements of paper products do not occur, he pointed out. However, the seaway should help B.C. lumber shipments consigned to Great Lakes points.

Wheat exports from Pacific-Coast outlets were destined for three main areas, he stated, namely the Near East, including Japan, the West Coast of South America, and Western Europe. Prince Rupert and Vancouver were the logical outlets to the Near East. Argentine grain to South-American points had to be bagged. Canada has a large bagging plant on the west coast, which will maintain the shipping route for grain via the west coast.

The shipping pattern of grain was mostly the direct result of availability of spot cargo on the west coast. Partial loads of wheat out of west-coast ports helped to solve shipping companies' problems. The Alberta Wheat Pool had recently decided to enlarge the capacity of its Vancouver elevator by 50 per cent, he added. This was evidence that there was no fear of the Seaway drying up the flow of wheat through Canada's west-coast ports.

NOTE: The illustrations accompanying this article are reproduced by courtesy of Ontario Hydro except Figs. 8 and 13, for which we are indebted to Canada Steamship Lines and to New York State Power Authority respectively.

KMW Water Turbines. An admirably produced booklet received from AB. Karlstads Mekaniska Werkstad gives a detailed description of two of Sweden's famous power stations—Harsprånget and Kilforsen. Naturally, particulars of the KMW turbines receive pride of place, but the main civil-engineering features of the two stations are also adequately covered. The booklet is written in perfect English.

Welded Details for Single-Storey Portal Frames. This is the title of the latest brochure published by the British Constructional Steelwork Association, Artillery House, London, S.W.1, and includes detail drawings and working descriptions of all kinds of joints used in these structures. A nominal charge of 2s. 6d. is made for this publication.

Hydro Power in Kenya. The winter 1955 issue of *The Harland Magazine* published by The Harland Engineering Co. Ltd., Alloa, Scotland, contains a particularly interesting article by A. Feiner, who is Engineer-in-Charge, Water Turbine Contracts Department, on hydro-electric power in Kenya. This firm has supplied the greater part of the turbines and alternators for hydro-electric development in that country. Two 4,000 kW sets were supplied to the Low Tana development in 1955, and this article is mainly concerned with a description of the scheme. Incidentally, another article in the issue gives a fascinating description of the hydraulics and mechanics of the honey bee!

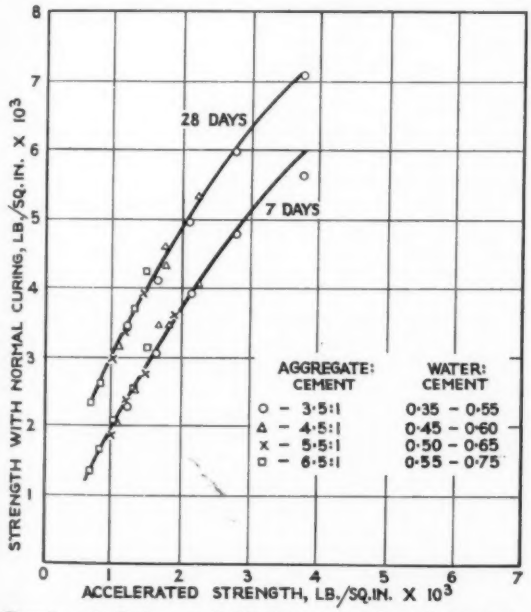
The EM-Kayan. The February 1956 issue of the Morrison-Knudsen Company's house journal contains several articles dealing with hydro-electric schemes for which the company are engaged on construction. Two relate to Brazilian schemes, one being about the dredging of the Pinheiros power canal and the other about the excavation of the new Cubatao underground power house, which, together with the existing surface station at Cubatao, will be served by the Pinheiros canal. A third article is concerned with the Alcan Kitimat-Kemano development, for which the company are installing two further 140,000 h.p. sets, penstock linings, and ancillary equipment.

Accelerated Test for Concrete

Research now in progress at Queen Mary College, London University, may establish a testing technique that will enable the 28 day strength of concrete to be assessed in a few hours after placing

THE control of concrete quality is one of the daily preoccupations of civil engineers engaged on the construction of dams and similar structures, and the value of some reliable means of predicting the final strength of a lift soon after placing cannot be overestimated. Research on a technique of accelerated testing, which is now in progress under Professor J. W. H. King at Queen Mary College (University of London), Mile End Road, London, E.1, has reached a promising stage, and there appears every reason to hope that the reliability of the method used may become established. The research was requested, and financed, by the Port of London Authority, and it has been possible to develop a simple technique that will forecast the 7 or 28 day strength of concrete cubes seven hours after mixing.

Standard test cubes are cast in the usual manner, and half an hour after mixing they are placed in an oven—still in their moulds and with a top cover to prevent drying—and heated to a prearranged curing temperature. Present practice is to take an hour to raise the temperature and to keep it constant for a further five hours. Testing is carried out half an hour after heating ceases, giving a total of seven hours from mixing to testing. Duplicate cubes for the 7 day and 28 day tests are mixed at the same time as the accelerated-test cubes, maintained in a humid atmosphere at 68° F. for 24 hours and then kept under water until tested.



Graphs of 7-day and 28-day strengths of concrete against accelerated strength. Heating time 6 hours, total time 7 hours

A comprehensive series of tests has been carried out on a range of mixes using Thames ballast as aggregate and Blue Circle cement of one batch, the curing temperature adopted being 200° F. Details of the mixes, together with the results obtained, are given in the accompanying graph, and it will be seen that the scatter is small.

Tests are now in progress to discover the effects of manufacturing variations in a standard cement, and of small modifications to the testing regime. As yet it has not been possible to conduct a full investigation on the effects of differences in types of cement or of aggregate, but some tests of this kind have been carried out and have yielded interesting results. Cements of the Portland type, even when modified as rapid hardening, 417, or sulphate-resisting type, show no significant departure from the curves reproduced herewith, but for aluminous cements the curves give pessimistic results. Crushed aggregate and coarse sand tend to give greater strength at 28 days than indicated by the curve, although the 7 day strength is in accordance with the test.

It appears, too, that the optimum curing temperature for the Blue Circle cement used in the tests may be 185° F., as this gives a slightly higher early strength than temperatures close by on either side. Involuntary temperature variations could not, therefore, give optimistic errors in the results.

Generally speaking, variations in testing regime would appear merely to move the curves by an amount depending on the variation, and it is anticipated that for any given conditions a test regime could be developed which would yield curves as reliable as those already determined at Queen Mary College for the materials tested there.

The method is now being tried out on several works sites and in several laboratories. If further experience proves as satisfactory as there appears reason to expect, the civil engineer will have at his disposal a test of the utmost practical value. The ability to test concrete before its site counterpart has fully hardened and, if necessary, to remove it in that condition and before it is buried by subsequent work, would save both time and money.

A brief summary of this research was published recently in *The Chartered Civil Engineer* by the Institution of Civil Engineers, and full details of the investigation will be submitted eventually as a Higher

(Continued on page 193)

Evaporation from Lakes and Reservoirs

N. J. Cochrane, B.Sc., A.M.I.C.E., propounds a formula that is free from " variable constants " and correlates with available water-budget data within 10 per cent

ALTHOUGH the problem of evaporation from open water surfaces has been a major one for many decades, and indeed in the case of irrigation for centuries, in the writer's opinion the vast background literature that now exists is sometimes confused or even distinctly misleading. The word " evaporation " is itself frequently misused, and the greatest care must be taken in interpreting even quite modern technical papers in case the word is used for evaporation from evaporimeters or evapo-transpiration from land surfaces and plants. In some of the earlier literature it also seems to have included seepage. Perhaps the most difficult problem in some cases is to deduce whether the evaporation quoted is an actual measurement or only a calculation.

The actual measurement of evaporation from a large lake or reservoir is a formidable task. Some sort of hydrological balance has to be made over a considerable period of time and the measurement of all the physical variables is a considerable problem. It is not surprising, therefore, that actual water-budget measurements of evaporation are very few, although one might not expect this to be so from the positive tone of some theoretical papers. It is, however, accepted by most engineers that some sort of estimate of evaporation from large bodies of water may be made by the judicious study of climate and of results from various types of pan evaporimeter. In addition there are a number of quasi-theoretical analyses using either known or assumed meteorological data, for example, the methods proposed by Sutton, Pasquill, Sverdrup, Thornthwaite-Holtzman, Penman, Ferguson, etc. All these methods have their supporters among physicists and meteorologists, but the significant thing for the practising engineer is that they all rather differ from each other, and therefore, none is likely to be exhaustive. The last two methods mentioned are basically radiation-balance approaches and seem especially attractive.

So far as engineering hydrologists are concerned, when dealing with varying natural phenomena it is very desirable to make use of analogies with similar situations elsewhere. This probably explains the generally empirical approach of engineers to such problems. At the same time the art of hydrology is over-well supplied with empirical analyses frequently including our old friends the factors k or c. The innocent interpreter must therefore hold very closely to the actual conditions in which the formulae were intended to operate, or he may find the result of his analysis to be a Miscalculation by Variable Constant out of Empirical Algebra.

After a good deal of analysis the writer felt dissatisfied with the available approaches to evaporation from large volumes of water, and decided to attempt an observational study of the available data and to try to deduce an empirical but logical formula which would fit the observed data reasonably well, and which, most important, would not include any " variable constants." There would not then be any doubt of the actual mathematical value of the calculated evaporation.

In the first instance, a random sample of some 80 evaporation records from evaporation pans spread widely over the world were studied. No evaporimeter smaller than the 4 ft. diameter U.S. Class A. Pan was considered, i.e., Piché and Wild evaporimeters were excluded. For many of these sites climatic information was also available, and the writer considered that he need only relate his evaporation analysis to the three " end-product " climatic phenomena: mean annual air temperature, mean annual wind speed, mean annual relative humidity. Somewhat similar work has been done by Blaney and associates in the United States, mainly directed towards the evapotranspiration or consumptive use of water by crops and plants. Blaney's work was apparently limited to low wind speeds and included a factor for daytime hours.

Evaporation from open water should be a direct function of temperature and wind speed and an inverse function of relative humidity, and the writer has found the following expression to cover a wide range of climates:

$$E_e = \frac{T^2}{100}\sqrt[3]{\frac{U+3}{20H_r}} \cdot \left(\frac{60}{H_r T}\right)^{0.8}$$

where:—

E_e is the calculated open water evaporation in inches per annum.

T is the mean annual temperature in °F.

U is the mean annual wind speed in miles per hour at 10 metres above water surface level.

H_r is the mean annual relative humidity expressed as a fraction.

Although this expression covers a large proportion of evaporation data deduced from pans, there still remains a considerable scatter in the relationship, and this seems almost certain to be the result of the following major factors:—

(a) It is quite difficult to obtain accurate data from many of the pans because of splash out during rainstorms and wind.

(b) It is even more difficult to get accurate recording of results in many countries, either because of the calibre of the observer or because of interference with the pan by animals or vegetation.

(c) It is difficult to get accurate climatic data.

(d) In many cases the climatic data had to be obtained from synoptic overall charts, and although these may be fairly accurate on a long term basis, they can be quite seriously out on a short-term basis.

(e) The evaporation data and the climatic data may not be for the same periods. For example, it is known that the annual evaporation from a pan in the Carribean area varied from 90 to 130 per cent. of the mean of 28 years of observations.

It will be seen, therefore, that there is built into any analysis of this nature a considerable scatter, and this would not permit the writer to claim that his formula is in advance on any of the other empirical approaches, unless there were available some data of special value. It is equally true, however, that the proof of the pudding is in the eating, and although water-budget measurements are very few they do exist, and some of them are the results of most exhaustive enquiries. In addition there are some most carefully organised pan experiments.

The water-budget figures are however the most important and are as follows:—

Lake Hefner. This was a subject of a massive controlled official experiment in the United States, and both the water budget and meteorological data are authoritative, and for the same period. Nevertheless, some care must be taken in abstracting the results as some of the data have been "adjusted." The water-budget figure is 52 in., and the writer's calculated value is 55·8 in. per annum.

Zugersee. This is quoted by Follansbee and is said to be a true water budget. However, the writer had to deduce the wind speed synoptically. The water-budget figure is 30·5 in. and the writer's calculation 30·3 in.

Staines Reservoir. This is the subject of a water-budget study but full data are not yet available. The climatic data are authoritative. The writer's calculated figure is 33·8 in. per annum and the water-budget data at present available are within the range of variation mentioned later.

Salton Sea. This is an authoritative water-budget study carried out by Mr. Blaney of the United States Department of Agriculture, and the climatic data have been kindly given to the writer by him. The water-budget figure is 68·5 in. and the writer's calculation 62 in.

Aswan. This is a very long-term pan floating in the reservoir, and the meteorological data are also for a very long period. The pan evaporation must be less than 105% of the true reservoir evaporation which is taken as 101·8 in. The writer's calculation is 109·8 in.

It will be noted that the correlation is between ± 10 per cent., which seems reasonable in the light of the type of data available. In any case, the analysis has been taken as far as the writer can at present, until further water budgets become available, although he hopes to complete a water-budget analysis of evaporation from Lake Nyasa in the foreseeable future.

A further point to be borne in mind is the change of local climate brought about by a new reservoir. This is frequently said to be small, but the writer suggests it may have a considerable local effect. For example, a limited exercise in West Africa revealed that the relative humidity in a shallow river valley was some 15 per cent. higher than that at a meteorological station a few miles away. This suggests that if the unreservoired climatic data are inserted in the writer's formula the answer may be on the high side.

Water-Power Resources of Canada

The Water Resources Branch has issued its annual review of the potentially available and of the presently developed water powers of Canada. The latest available information regarding water power in each province is summarised and a brief discussion of overall resources is given under such divisions as provincial distribution, current progress in development, growth of development, general utilisation, and relationship of development to population.

The presently recorded water-power resources of Canada are shown as totalling more than 29 million horsepower under conditions of low stream flow and of nearly 51 million horsepower at average flow, the latter figure representing a feasible turbine installation of nearly 66 million horsepower. The total turbine installation at the end of 1955 is given as 17,511,148 h.p. indicating that only about 27 per cent. of available resources has been developed. During 1955 hydro-electric construction was very active, with 839,630 h.p. of new capacity coming into operation and with good progress being made on other new developments; additional projects also were being investigated or planned. Of hydraulic plants, 87 per cent. serve as central-electric stations and, in 1955, production reached a new high level. The pulp-and-paper and the mineral industries are the more important consumers of hydraulic power. The installed capacity of water-power plants in Canada now equals 1,122 h.p. per thousand of population.

Copies of this review (Bulletin No. 2501) may be obtained free of charge on application to the Director, Water Resources Branch, Department of Northern Affairs and National Resources, Ottawa.

From page 183

If upon study the plan for tidal power here proposed is found suitable for the Severn Barrage, the power available would be notably increased over figures so far proposed. While according to the news items, the St. Malo project will utilise flow in both directions in the pool, the performance characteristics of the I.W.W. would seem to be helpful. Other notable tidal projects have been described from time to time.

The writer would be ready to discuss various details of the present plan with any interested engineers.

From page 191

Degree thesis of London University by Mr. N. G. Bondre, a former research assistant at Queen Mary College, who carried out the bulk of the experimental work. It is hoped that a more fully detailed report of the work carried out to date than that appearing in *The Chartered Civil Engineer* will be published in a few months' time.

Professor King is anxious to hear comments on the technique from any concrete users who are interested enough to carry out tests on their local materials. If full details are submitted of any tests which apparently do not comply with the published curves, it should be possible to determine whether this is due to local materials or to local small variations in operating technique. Any reports would thus be of great value in helping to prepare a standard routine for the future.

Book Reviews

Cedar Bluff Dam. U.S. Bureau of Reclamation, Denver, Colorado. 90 pp. 47 ff. Photo-lithographed publication in stout paper covers. No price quoted.

This publication is the latest in the series of Technical Records of Design and Construction published by the Bureau, and we need do little more than remind our readers of the detailed information given in these publications and of their unquestioned technical value.

Cedar Bluff dam was constructed in 1949-52, and is located on the Smoky Hill River, a tributary of the Kansas River, 18 miles south-west of Ellis. It was built for flood control, irrigation and fish and wildlife preservation. It is of zoned rolled earthfill construction, 134 ft. above streambed, 199·4 ft. above lowest excavation; it has a crest elevation of 2,198 ft., a crest length of 12,560 ft., and contains 8,488,600 cu. yards of material. The spillway is of the concrete overflow open-channel type, having a crest width of 150 ft. 6 in. There is one 14 ft. 6 in. by 10 ft. orifice and eight 5 ft. square gated sluices.

The Electricity Supply Industry in Europe. Published by the Organisation for European Economic Co-operation, 2 rue André-Pascal, Paris-XVI^{e}, 132 pp. Price, 500 F. fr., 10s., $1·50.

This overall study of the situation in the electricity-supply industry in Europe made by the O.E.E.C. Electricity Committee analyses the recent trend in the industry and gives some details on prospects for development from 1955 to 1960. Since the beginning of 1954, the electricity-supply industry has been going through a period of great activity. Consumption for all Member countries combined rose from 300,000 million kWh in 1953 to 328,000 million kWh in 1954, an increase of 9·3 per cent. for the year. Available information indicates that expansion continued at the same rate in 1955. Forecasts up to 1960 reflect a continual and sharp tendency to rise, without showing, so far, any sign of saturation.

To meet this continuous increase in demand, all the countries recognise the need to intensify their investment effort during the next few years. Total installed capacity, 90 million kW at the beginning of 1955, should reach 120 million kW in 1960. A detailed analysis shows a slightly faster increase for thermal than for hydro capacity, as most of the more economically workable hydro resources are already extensively exploited, particularly in Central Europe, and it would be difficult to continue developing this sector as rapidly as in the past. In 1955 alone, investment in production and distribution plant amounted to the equivalent of $2,500 million, i.e. about 7 per cent. of Member countries' gross capital formation.

The enquiry conducted in Member countries shows that the efficiency of thermal power stations is progressively improving.

Power exchange between interconnected countries has intensified, rising from 4,000 million kWh in 1953 to 5,000 million kWh in 1954. Although, in absolute terms, power exchange represents only a small proportion of production (2·5 per cent. in 1955), it is of great economic importance and its further development offers numerous advantages: reduction of total installed capacity by offsetting the load curves in different countries, better use of the less-expensive power stations which might otherwise not be working to full capacity, and reduction in the number of stand-by generators needed to cope with incidents in production or distribution.

The rapid increase in electricity consumption makes it necessary to seek means of expanding production as economically as possible. The report gives information on the development of under-exploited water-power resources in Europe and the Overseas Territories, on the harnessing of tidal energy and the possibility of transferring industries which are heavy consumers of electrical power to areas with high water-power resources.

Finally, the report provides information on the production of electrical power from nuclear energy.

Regulungstechnik. By Prof. Dr. Ing. Georg Hutarew, Springer-Verlag, Reichpietscufer 20, Berlin, W.35. 177 pp., 198 ff. Price, 18DM., linen-bound 21DM (£1 15s. 9d.).

Water-turbine governor textbooks are uncommon, and the best known are, perhaps, those of Tenot and Fabritz in French and German respectively. These form excellent descriptive introductions to construction and operation, but modern regulation theory is needed to put design on a scientific basis.

Servomechanism analysis has advanced recently at a considerable pace, and while this has benefited other branches of control engineering, little has been published which is applicable to water-turbine governors where oil is the operating medium. Although it has been suggested that analysis by analogy with electrical circuits is possible, this has proved impracticable, particularly for those who have neither time nor mathematical inclination for treatment by abstract reasoning. It follows, therefore, that Prof. Hutarew's book should merit the attention of hydraulic engineers.

After explaining the non-linear character of governor equations and definitions according to German standard DIN19226 for proportional, integral and differential circuits, the first two chapters are devoted to differential equations and loop circuits generally leading up to frequency response, its expression as a curve in the complex plane and the resultant vector-radius/phase-angle relationship for elements in series, parallel and differential circuits. These concepts form the basis for study of the principal water-turbine governor components and the combined action under steady state and transient conditions.

Commencing with single and double-lever systems, frequency response is determined with rigid and elastic connections introducing delay through spring and oil-dashpot couplings. A similar treatment is applied to various types of speed pendulums relating mass and damping to centrifugal action, displacement and force exerted at the collar. The accelerometer pendulum is briefly mentioned.

Lastly, servomotor and oil-distribution-valve arrangements for single and multiple stages are examined in conjunction with the appropriate forms of return gear to give frequency response and transfer functions.

The principles outlined in the preceding chapters are extended to representative examples of continental

governors designed by Escher Wyss, KMW and Voith, using speed measurement, and two based on speed and acceleration by Charmille and Vevey. The treatment employs simplified schematic and block diagrams from which the equations for overall behaviour are derived.

An approach to turbine-governor and regulating-gear motion under transient conditions is made for Francis guide vanes and Pelton needles, using topographical diagrams expressing performance in terms of unit speed and power, and bringing in the influence of waterhammer, generator flywheel effect and external load characteristics in a simplified way. Kaplan turbines with double regulation are introduced under the heading of mixed circuits.

Finally, criteria for investigating stability are summarised by reference to the Hurwitz differential equation coefficient relationships, the Leonhard graphical method and frequency response according to Nyquist.

Although the mathematics are relatively simple, practical engineers would obtain a better appreciation of the physical significance and importance of the factors which enter into the response of the individual components and the complete governor if numerical values and worked examples were included. The absence of such information makes the equations rather formidable to those who may have no idea as to pendulum weights, spring coefficients, dashpot-orifice characteristics, servomotor dimensions and capacity.

It is perhaps understandable that no reference is made to such allied matters as servomotor and distribution-valve design, pipework systems, oil-pressure supplies and pump characteristics or other associated problems such as valve lap, backlash, regulating-gear forces and friction, all of which enter into detailed performance analysis.

The text and diagrams are clearly presented and are easy to translate. This book effectively introduces a complex but important subject for hydro-electric engineers and ought to be followed by a further volume dealing with the practical aspects of governor design as developed from this special case of general servomechanism theory which the author has successfully adapted to his purpose.

"Empfehlungen des Arbeitsausschusses 'Ufereinfassungen'" (Recommendations of the Working Committee for Bank Protective Works). Published by Wilhelm Ernst & Sohn, Hohenzollerndamm 169, Berlin-Wilmersdorf. 6 in. by 8 in., 56 pp., 9 ff. Price in Germany, paper wrappered, DM.8·80.

The German Working Committee for Bank Protective Works, appointed in 1949 by the "Hafenbautechnische Gessellschaft" (Association of Harbour Works Technicians), also acts since 1951 as No. 7 Study Group of the "Deutsche Gesellschaft für Erd- und Grundbau" (German Association for Earthworks and Foundations), and has thus extended its activities from harbour structures to general earthwork and foundations. The committee's duty is to bring about a simplification and standardisation of the many, often widely differing calculation methods and planning procedures heretofore in use, and to submit from time to time recommendations for discussion in the technical press. The objections and suggestions received are then thoroughly examined, and, as the case may be, incorporated in final recommendations which are published in a comprehensive yearly report. The present volume, which covers all recommendations issued up to August 1955, is divided, according to the nature of the work involved, into nine main sections proceeding from soil investigation, earth pressure and ground resistance, through load conditions and bank equipment, to sheet piling, anchoring and massive bank walls. A schedule of items listed for future consideration by the committee is appended; it includes new sections dealing with the enclosing and shoring of foundation pits, sills, guide walls, and strengthening of sloping banks; a special section will be devoted to control measurements on completed structures, and model tests. From all these headings it is obvious that this neat little booklet contains a great deal of information which can be applied to the civil-engineering side of hydro-electric developments. A particularly noteworthy feature of these recommendations is the terseness of their style.

Kempe's Engineer's Yearbook. Morgan Brothers (Publishers) Limited, 28 Essex Street, Strand, London, W.C.2, 1956 (61st edition). Two Volumes in case. 3,000 pp. Price 75s. net. Postage 2s. 6d.

This famous yearbook is such a familiar friend that little needs to be said beyond the fact that the usual painstaking annual revision has been undertaken. Changes made in the 1956 edition include an entirely new chapter on "Foundations and Earthwork"; the rewriting of "Aerodynamics" and "Aircraft Propulsion"; additions to the chapters "Electrical Engineering," "Electronic Engineering," Gas and Gas Engineering," "Steam Engineering," "Steam Turbines," "Mining Engineering," "Explosives," "Industrial Safety and Protection," "Concrete and Reinforced Concrete" and "Depreciation," as well as many revisions in other chapters to bring them up to date. In all there are 79 chapters covering practically every branch of engineering.

International Electrotechnical Vocabulary (2nd Edition), Group II: Static Convertors. International Electrotechnical Commission, Geneva. Price 5 Sw. Fr.

This publication is one of the series of booklets, each comprising one section or " group " of the second edition of the International Electrotechnical Vocabulary, containing some 110 terms and definitions dealing with static convertors, arranged under the following headings: General Terms, Gas-filled Rectifiers, Mercury-arc Rectifiers and their Components, Circuits and Operating Conditions, Miscellaneous Convertor Components. Following the pattern laid down for the second edition of the International Electrotechnical Vocabulary, the terms and definitions are given in English and French, whilst the terms only are given in Dutch, German, Italian, Polish, Spanish and Swedish. There is an alphabetical index of the terms in each of the eight languages used.

Waterhammer Analysis. By John Parmakian. Published by Prentice Hall, Inc., New York.

Our British and European readers may like to know that this book, which was reviewed in our January 1956 issue, is now available through Bailey Bros. & Swinfen Ltd., 46 St. Giles High Street, London, W.C.2, price £2 12s. 0d. net.

A New Computing Service

The English Electric computing centre in Marconi House, London

Among the most complex mathematical problems which the hydro-electric engineer has to solve are those relating to surge oscillations in the pressure pipelines feeding water power stations. In the past, many hundreds of thousands of hours of the time of most highly trained engineers must have been occupied in solving these and other similar design problems; and much of this time has in fact been unproductive, since there has always been the necessity to discard a very high proportion of the intermediate work, much of which must have been carried out on a trial-and-error basis.

The advent of atomic power will mean that the hydro-electric engineers, both those concerned with the manufacture of plant and those who have to operate the completed schemes, will perforce need to streamline their design and estimating methods, with the dual purpose of employing their highly qualified staffs to the best advantage and also of being able to provide, much more rapidly than ever before, data which will enable to ultimate economic justification of a proposed water-power project to be assessed.

All branches of the hydro-electric profession will therefore welcome any extension of the computing services now gradually being made available to industry. One such service is of particular interest, since it emanates from the works of a firm which is itself a leader in water-power progress—The English Electric Co. Ltd. This firm has lately installed in its London office, at Marconi House, Strand, a digital electronic universal calculating engine (DEUCE) which is available for the use of firms outside the Company. Moreover, the English Electric service includes the use of a large and continually growing library of programmes and sub-routines which have been previously prepared for the solution of many and varied problems.

The information fed into DEUCE is prepared in the form of punched cards, and the information is returned to the operator in a similar form. Very large calculations are made in times of the order of tenths of a second; and for the solution of 60 linear algebraic simultaneous equations—a task which would take a mathematician perhaps three months by conventional methods—a time of 18 min. only is needed.

The service is open to all engineers, and it is understood that the cost is of the order of £30 per hour. The customer may choose to set up his own problems on the machine, with the aid of the English Electric staff, or they may entrust the whole solution to them, in cases where the extent of the problems concerned do not appear to warrant full time use of the machine.

Industrial Plugs and Sockets. Reyrolle & Co. Ltd. have issued a pamphlet giving full particulars of "Easigo" metal-clad protected-type plugs and sockets of 5, 15 and 30 A capacity with scraping-earth connections. They are intended to form a complete system of connections from a wall outlet to a portable appliance.

Onions Compaction Rollers

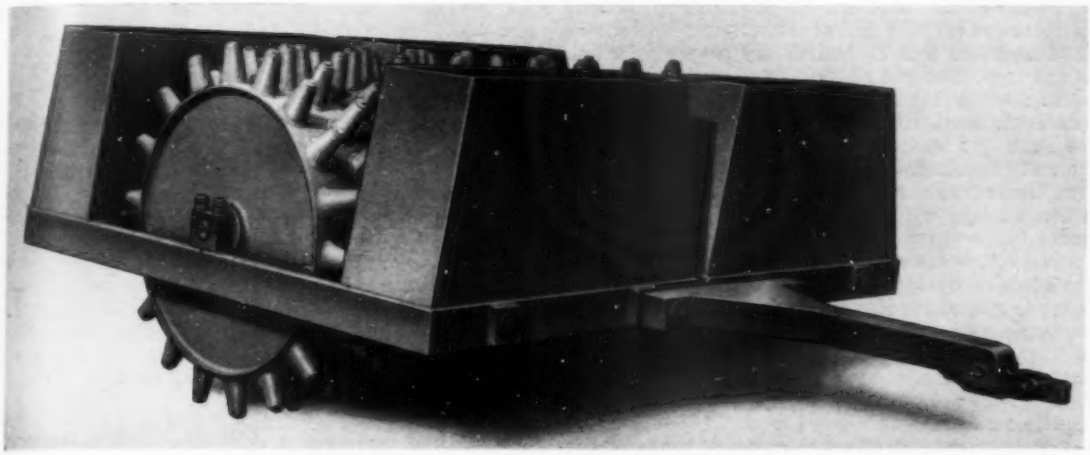


Fig. 1. Onions sheepsfoot roller assembly with two units side by side

Onions & Sons (Levellers) Ltd. have now entered into the manufacture of compaction rollers for use with heavy crawler tractors. Two types of rollers are produced, the sheepsfoot, and the rubber-tyred compactor, and between them the requirements of practically any type of soil compaction can be met.

The sheepsfoot "Compacta" roller is produced in one size, a normal arrangement comprising two individual units joined by articulated joints, either side by side, as seen in Fig. 1, or in tandem. Other arrangements with 1, 3 or 4 individual units are available. Each unit consists of a drum which can be filled with water for ballast, running on a fixed axle attached to a rectangular frame; sand or earth ballast boxes are mounted on the frame. Tapered feet are welded to the periphery of the drum, there being 36 axial rows each with 4 feet, these being staggered to give eight lines of compaction. Each foot is 9 in. long and has a hardy alloy-steel pad 3 in. in diameter welded to the end.

By having facilities for water or sand ballasting, the ground pressure can be adjusted from 330 to 920 lb. per sq. in. This variation is sufficient to meet all the normal requirements of any operation where a sheepsfoot roller would be employed. When joined together as a pair, the articulated joints allow the units to oscillate independently, permitting the complete roller to conform to surface irregularities likely to occur during the initial stages of compacting any type of material.

The Onions rubber-tyred compaction rollers (Fig. 2) are produced in two sizes, each one comprising a group of independent units enclosed within a rectangular yoke. An adjustable towbar enables the roller to be kept in trim when towed behind a suitable tractor. The yoke may be altered to take from three to six units. Each independent unit comprises a wheel and tyre supporting a container large enough to carry sufficient sand ballast to load the tyre to its safe maximum.

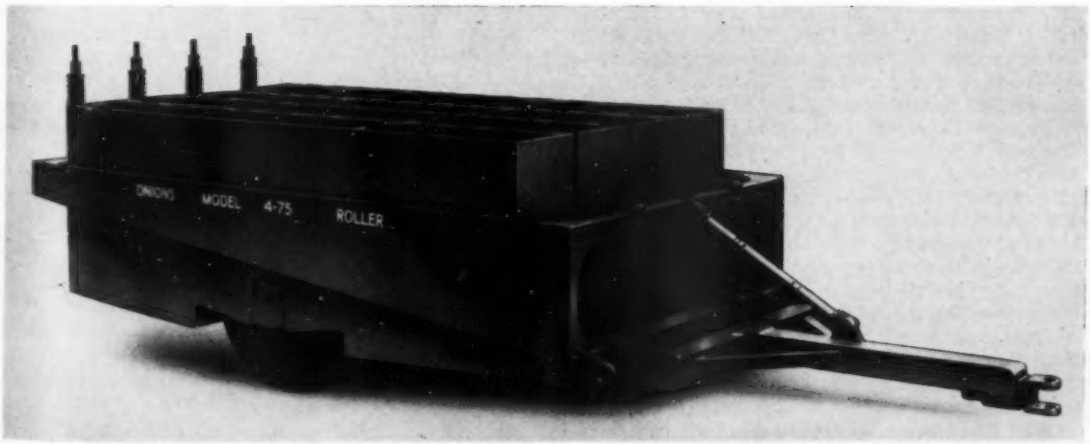


Fig. 2. Onions rubber-tyred type of compaction-roller assembly

The compaction units are hinged to the front of the yoke and can move independently. At the rear, each unit is attached to a buffer spring to damp excessive oscillation. These springs preserve the stability of the assembly and do not transfer any appreciable load from one unit to another. By having each unit towed from the front of the yoke with the stabilising springs at the rear, a high degree of uniform compaction is obtained. Each unit is free to move vertically with the tyre imposing a steady and even load over ground irregularities. The consolidation provided by this Onions roller eliminates soft patches particularly when dealing with materials which include small rocks.

The yokes on each of these two sizes of rollers can be adjusted by spacing bars so as to accommodate three to six independent units, a standard model being equipped with four. The total weight of the four-unit Model "75" when fully ballasted with wet sand is 50,500 lb. giving a load of 760 lb. per inch of tyre rolling width. For the four-unit Model "150" the equivalent figures are 105,500 lb. and 1,185 lb.

The requirements of projects necessitating compaction at some stage of the operations differ considerably, and probably no two jobs will be identical. This aspect of compaction was borne in mind by Onions when designing both types of rollers, and in consequence each model has a high degree of flexibility as far as the ultimate ground pressures are concerned. At the same time the standard models can be adapted to meet different conditions by the addition of extra units.

It is impracticable to lay down any hard and fast guide to where a sheepsfoot roller is preferable to a rubber-tyred compactor or vice-versa. Operating conditions, contract specifications and, to a certain extent, personal preferences largely determine the choice of equipment. It is however possible to outline the performance characteristics of each type which when applied to any particular project will help to determine the choice.

The rubber-tyred roller is capable of dealing with thicker layers of material as the compactive effort is delivered to a lower depth and is capable of achieving a higher percentage of maximum density with a fewer number of passes on most materials. This type of machine is particularly suitable on loose soils which have a tendency to flow under pressure. Materials having small cobbles or rocks fall into this category and it is here that the rubber-tyred compactor can help to keep down production costs by avoiding the necessity of removing the rocks in order to achieve a really high degree of compaction. Because of their high tyre loadings and inherent stability, the Onions compactors can be operated at reasonably fast speeds, an important factor when dealing with large quantities of materials which have to be placed in position by other equipment. This latter point illustrates the importance of achieving a balance between the capacity of the plant devoted to compaction and the equipment supplying the fill. Once this balance is disturbed operating costs will rise considerably. The rubber-tyred compactors have demonstrated their ability to consolidate efficiently, fills of a higher moisture content than is possible with a sheepsfoot roller. The heavily loaded tyre will overcome pore pressures in the soil, squeezing the excess moisture to the surface where it will evaporate. For the same reason, materials compacted by rubber tyres seem to be able to shed rainwater to an unusually good degree.

From the above it would seem that most compaction jobs can be performed better with a rubber-tyred compactor than a sheepsfoot roller; generally speaking this is true, and is borne out by the increasing use of this equipment. But there are still many operations where the sheepsfoot roller provides the ideal type of compaction, due to its ability to apply a high degree of consolidation to the surface of a material. This form of compaction is often the most suitable for preparing the sub-base of a road where the soil conditions are favourable. Where earth is dumped roughly in windrows, the Crawler tractor towing the sheepsfoot roller can often use its dozer blade to spread the material just prior to the roller passing over. This operation is frequently found to be the most economical as it allows the tractor to perform two jobs at once. The world distributors for Onions earthmoving equipment are Jack Olding & Co. Ltd., Hatfield, Herts., England.

Blaw Knox Concrete Placer

Blaw Knox Limited, 94 Brompton Road, London, S.W.3, have developed a pneumatic concrete placer which is claimed to be able to deliver a mix over any required distance up to more than 1,000 ft. horizontally or 100 ft. vertically. It conveys up to 35 cu. yards of concrete per hour through a 6 in. pipeline direct

Fig. 1. Blaw Knox concrete placing machine

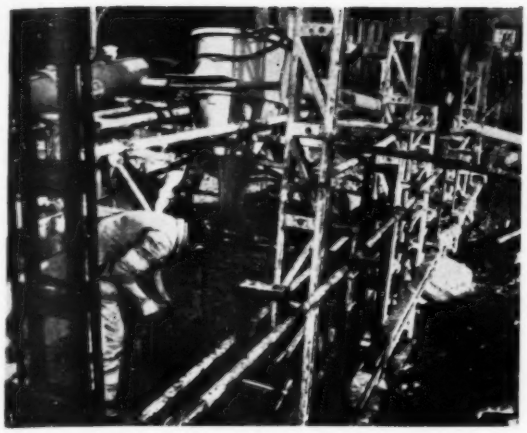


Fig. 2. Discharge unit in operation

to the placing point, and will handle both normal mixes and also high and low-slump concrete with aggregates not exceeding 2 in.

As will be seen from Fig. 1, the machine consists of a pressure cylinder of 17·5 cu. ft. capacity, with a receiving hopper at the top and a removable adaptor bend at the bottom. Concrete is discharged into the pressure cylinder, which is then closed by a cone-type valve. This has a pneumatic surface-cleaning attachment to ensure clean surfaces for an airtight seal. Compressed air, which is stored in an air receiver, is then admitted to the top of the pressure cylinder through a quick-action valve. The full batch is driven through the pipeline at a speed controlled by regulation of the air pressure in the cylinder. The design of the pressure cylinder is stated to ensure a regular flow of uniform concrete. It embodies an internal deflector cone to aid efficient discharge by preventing a core being blown through the concrete. A supplementary air pipe through the centre of the deflector cone is used as a booster, enabling harsh mixes to be effectively transported. The pressure cylinder is tested to 150 lb. per sq. in.

The pipeline is constructed in 6 in. diameter steel tubing in 10 ft. sections; shorter sections are available to make up any final length to the nearest foot, and bends are supplied for delivery in any required direction. Quick-acting rubber sealed couplings enable the pipeline to be set up and modified rapidly by unskilled labour.

At the delivery is a discharge box which separates concrete and air, ensures smooth delivery and permits an accurate and clean flow of concrete to narrow forms and inaccessible places. A central baffle within the discharge box divides the flow of concrete into two streams which are reunited at the far end of the box. This arrests velocity and minimises the force of discharge. In Fig. 2 can be seen the discharge end of a Blaw-Knox concrete placer at work on the Wilderspool Crossing at Warrington, Lancashire (contractors, Harry Fairclough Limited, Warrington). For tunnel lining the discharge box is dispensed with, the delivery pipe being led direct into the space between the shuttering and the tunnel wall.

For dam construction the concrete placer should be an attractive proposition in suitable conditions, as its long horizontal carry may well dispense with the need for more conventional methods of concrete transport.

Waldshut Pumped-Storage Plant. J. M. Voith, G.m.b.H., Heidenheim (Brenz), Germany, have published in English a 20-page illustrated brochure describing the Waldshut pumped-storage power plant on the banks of the Rhine. Waldshut is the lowermost of a series of three pumped-storage plants owned by the Schluchseewerk Company, and the Voith Company supplied nearly all the hydraulic equipment for all three stations. In all stations the units consist of a turbine/combined-alternator-motor/pump combination, those at Häusern and Witznau (the upper and intermediate stations) being of the vertical-shaft type, and those at Waldshut horizontal-shaft. At Häusern there are two units each comprising a 46,000 h.p. Francis turbine and 26,700 h.p. pump operating under a head of 689 ft. There is also a 750 h.p. house turbine. At Witznau there are four units each driven by a 75,000 h.p. Francis turbine under a head of 853 ft. At Waldshut there are four units driven by 60,000 h.p. Francis turbines under a head of 469 ft. and incorporating 24,100 h.p. pumps. At Witznau and at Waldshut the pumps are run up to speed by impulse-type starting turbines and then connected to their alternator-motors by clutch couplings. At all stations the Voith Company also supplied the governor gear, valves, gates, stoplogs and trashracks. At Waldshut, which is the main concern of this brochure, this equipment included rotary shut-off valves and relief valves for the pumps, rolling and sliding stoplogs, trashracks, and rack-clearing equipment, and a compressed-air installation to dewater the pumps for starting and the turbines while pumping. The brochure is liberally illustrated by drawings and by a magnificent series of photographs, some of which are in colour. It has already been published in German, and the English version of a description of so interesting and important a scheme is to be welcomed.

Czechoslovak Heavy Industry. The two first issues to hand of the new monthly published under this style in Prague certainly prove that the Czechoslovak engineering undertakings, headed by such well-known works as Skoda, Poldi and Ceskomoravská-Kolben-Danek, fully keep in step with the advance of heavy industry in other countries. No. 1 is exclusively devoted to machine tools, but No. 2 contains a few articles of hydro-electric interest, such as "Production of Kaplan Turbines in Czechoslovakia," by Ing. Miroslav Druckmüller, "Design and Erection of Long-distance Transmission Lines," by Ing. Karel Pochop, and "The Handling and Storage of Bulk Cement on Large Civil-Engineering Constructions," by Ing. Fr. Kocandrle. The cover of the latter issue shows a handsome photograph in colours of a dam with ski-jump spillways passing over the generating station; these installations, we assume, are part of a stage of the great Vltava development. The journal is well produced on art paper, print and illustrations are excellent, and its English leaves nothing to be desired. There are also editions in French, German, Russian and Spanish.

Abstracts from the World Technical Press

High-Pressure Kaplan Turbines

The Kaplan turbine, owing to the flat characteristic of its efficiency curve combined with its high maximum efficiency, is particularly suitable in conditions where the head or the quantity of water available is subject to considerable variations. Thus, the tendency in design is to increase both unit outputs and heads, and in the Escher-Wyss works high-pressure Kaplan turbines are being designed for heads up to 80 m.

As the head is increased, the forces required to adjust the blades increase, and in consequence the hub diameter must be increased in proportion to the runner diameter to provide space for an adequately designed adjusting mechanism. The choice of the number of blades also involves arriving at the best balance between the hydraulic requirements, the reduction in stressing obtained by increasing the number of blades, and the increased complication of the adjusting gear. The design of the turbine-shaft stuffing box to cope with the increased pressure is also discussed.

Reference is made to a turbine supplied to Takeda station, Japan, delivering 9,680-12,500 h.p. at 360 r.p.m. under a head of 36·9-41·2 m., to a turbine for Requejada station designed to give 2,980-5,730 h.p. at 500 r.p.m., under a head of 27-57·5 m., and to a turbine for Montefurado, giving 8,210-18,750 h.p. at 300 r.p.m. under a head of 19·6-35·1 m.

Most of the article is concerned with a description of the turbine built for the Barcis station in Upper Italy, and of the acceptance tests on the machine. This turbine operates under a head ranging from 28·5 to 63·5 m. and develops 6,145-13,600 h.p. It can run either at 500 or at 420 r.p.m. so that it can serve either a 50 or a 42 c.p.s. system as required. To prevent cavitation the runner had to be placed 3·9 m. below minimum tailrace level, but owing to the wide fluctuations in tailrace level—up to 7·9 m.—the generator, in order to be above maximum flood, had to be placed a long way above the turbine. It was therefore necessary to guide the shaft in one turbine collar bearing, two intermediate bearings, and two generator bearings, the thrust bearing being located on top of the generator.

The steelplate spiral casing was pressure tested at a head of 125 m., and was grouted in at an internal pressure of half the operating pressure so as to reduce stresses in the concrete during operation.

Needle bearings are used on the guide-vane links to reduce the adjusting forces necessary. With high-head Kaplan turbines, in the event of sudden load rejection it is not possible to make an emergency closure of the blades as the stresses on the operating mechanism would be too great, so a quick-acting rotary valve is placed in the supply pipe which is tripped to close automatically in the event of an overspeed. Simultaneously air is injected to prevent lifting of the runner due to vacuum formation.

Much of the article is concerned with the manner in which the acceptance tests were carried out. Measurement of the water quantity proved to be the most difficult problem owing to the lack of a satisfactory location for the cross carrying the current meters. Eventually this was placed in a reinforced-concrete conduit crossing a ravine and forming part of the pressure tunnel before the surge tank, but even this location was 2·56 diameters ahead of a slight bend, which had to be allowed for in the results. A short taper immediately before the spiral casing was used as a kind of venturi meter to provide a check. During the trials two of the 25 current meters failed, but the tests were not interrupted, and the article describes how the missing readings were intrapolated.

The tests were carried out at a head of 48 m., and 89 per cent. efficiency was registered at 9,500 h.p., which is above the guarantee. By correlating this figure with results from model tests, a maximum figure of 90 per cent. under 63·5 m. head should be obtained.

After 8,000 operating hours under different heads and loads the runner wheel was inspected and showed no signs of wear. (J. Wucherer and R. Vaucher. *Escher-Wyss News*, No. 1, 1956, p. 5, 10 pp., 15 ff.)

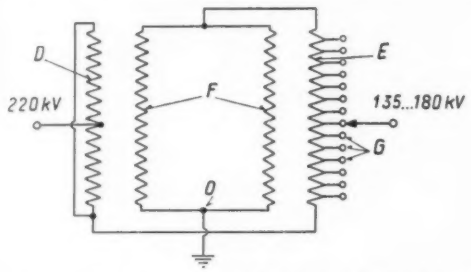
Model Tests

A comprehensive account is given of the tests carried out at the Chatou laboratory on small-scale models of the Montelimar intake and impounding works with a view to determining the location and layout of the installations, as well as the most favourable mode of operation and the construction schedule, due account being taken of navigation requirements. The Montelimar plant is sited immediately upstream of the Donzère-Mondragon development. The storage level, at 77 m. against 58 m. at Donzère, creates a gross head of 19 m., and the corresponding backwater at low-water level stretches over 13 km. The dam will impound a depth of 12 m., against 8 m. at Donzère. The diverted discharge of 1,850 cu. m. per sec., slightly above the mean Rhone discharge, exceeds the corresponding figure at Donzère by 320 cu. m. Headrace and tailrace will have a length of 12 and 2 km. respectively. The model used (1 : 60 scale for most tests) reproduced the Rhone bed 3 kg. upstream and 1·5 km. downstream of the barrage, i.e., a river stretch of 4·5 km. A description is given of the works, as designed and located on the basis of the tests. The dam, now in course of construction, consists of six 26 m. openings, closed by two-leaf hook-type gates, and separated by 6 m. wide piers; the type of sill selected is only 20 m. in length, i.e., 10 m. shorter than the openings themselves, and in order to protect both sills and piers from scouring, a rubble apron, 2 to 3 tons in weight, has been set up around the piers. These aprons have proved perfectly stable at discharges up to 10,000 cu. m. (all sluices open) or 6,000 cu. m. (two passes closed). The normal storage level being 3 m. above the highest known floods, the banks of the river are protected by insubmersible dikes extending 4 km. on the right, and 10 km. on the left bank. The intake has been located 260 m. away from the dam, and its layout has been planned so as to divert alluvial and other material towards the dam. The model tests have also enabled the construction phases of the dam to be determined in the most favourable manner; for instance, cofferdamming of the openings two at a time saved both time and costs. Besides, it has been possible to ascertain navigability conditions at any given moment, and to eliminate any solution which would have rendered navigation too difficult or even impossible. All the control tests effected on site during the first two construction stages have proved the re-

liability of the model tests, both as to flow (velocity, depth) and alterations of the river bed at flood periods. (J. Chabert, Chatou Laboratory, *La Houille Blanche*, Vol. 10, No. 3, July 1955, p. 369, 23 pp., 35 ff.)

Auto-Transformers for Super-Grid Interconnection

The increasing growth of 220 and 380 kV supertension grids has caused a continually increasing demand for coupling transformers to interconnect these grids with those of the next lower voltages, namely 150 and 220 kV respectively. The auto-transformer is specially suitable for this duty. The Oerlikon Engineering Company has supplied the first Swiss-made transformer group for this purpose to the Bernische Kraftwerke (BKW) employing a novel method of connections. Two principal designs are available for auto-wound regulating transformers. One design consists of a fixed-ratio auto-transformer and a series regulating transformer supplied with varying voltage from a tertiary winding. This arrangement suffers from variable core losses and comparatively high copper losses, and is heavy. An advantage of this design is that the tap-changing switch has to deal only with comparatively low voltages and is not exposed to over-voltages. The second design is considerably simpler. The auto-transformer is provided with direct tappings on the low-voltage side, and the low-voltage system is connected through the tap-changing switch. This is the most economical solution with regard to transmission losses, and the required high insulation level of the tap-changing switch did not present too difficult a problem for modern technique. For these reasons this design was chosen. The transformers are of the two-limb construction, and the system of connections for a single-phase unit is shown in the accompanying diagram. (H. Lutz and A. Bally. *Bulletin Oerlikon*, October 1955, No. 312, 7 pp., 13 ff.)



E Regulating winding
F Lower-tension winding
G Contacts on tap-changing switch
O Neutral point, earthed

Damodar Valley Corporation

The undermentioned journal devotes a special number to the Damodar Valley Corporation and its achievements. In addition to articles of historic and administrative character, this particularly well-produced issue contains: "The Benefits of the Damodar Valley Project," by A. B. Ganguli; "Construction of Maithon and Panchet Hill Projects," by A. M. Komora; "Development of Thermal and Hydro-Electricity in Damodar Valley," by P. K. Bhattacharya; "Panchet Hill Project," by A. L. Das; "Maithon Underground Hydro-electric Power Station," by K. N. Chinnappa; "My Experiences in the Execution of Barrage and Irrigation projects: Damodar Valley Corporation," by D. Mookerjee; "Mechanised Earth-moving for Development," by S. S. Pillai. (*Indian Journal of Power and River Valley Development*, Vol. V, No. 6, June 1955, 84 pp., 52 ff., 10 plates.)

The 220 kV Ala-Roma Line

Following a brief survey of the extensive 220 kV system of the "La Centrale" concern, a description is given of the Ala-Roma link, which constitutes the backbone of the system. The line was constructed in six sections, which, at the outset, operated at 130 or 150 kV; of these, the Ala-Bussolengo and the Bussolengo-Colunga-Caselleria sections went over to 220 kV on November 22, 1953. A seventh section, Cassino-Rocca d'Evandro, was expected to be completed by the end of 1955. The preliminary studies, design data and construction work are reviewed at length. The main features of the line are: aggregate length, 545 km.; number of towers, 1,467; average tower height, 21·66 m.; maximum span, 920 m.; average span, 372 m.; maximum level difference between towers of the same span, 180 m.; maximum ratio, level-difference: span 155·8/317 = 0·491. (*L'Energia Elettricha*, Vol. XXXII, No. 8, August 1955, p. 718, 14 pp., 25 ff.)

Large Regulating Valves and Energy Dissipators

This paper deals with the use of scale models in the resolution of some problems arising in the design of reservoir outlets—namely, the hydraulic performance of regulating valves and the dissipation of the energy of their jets. After discussing the need for model tests and basic engineering requirements, the author outlines the theoretical considerations, and gives the results of an actual comparison of energy dissipation in a model and a full-sized completed structure. Some observations on model design and operation are included, and the paper concludes with a description of tests of proposals for new outlet works at a Victorian reservoir. These comprised the determination of discharge characteristics of model regulating valves, and the development of a relatively inexpensive energy dissipator which actually consisted of a simple shield fitted above the valves. (M. Lovely, B.E., *The Journal of The Institution of Engineers, Australia*, Vol. 7, No. 9, September 1955, p. 235, 5 pp., 10 ff.)

Measuring Pore Pressure in Earth Dams

This paper deals with laboratory tests carried out on an electrical pore-pressure gauge of the MDS-75 type manufactured by H. Maihak A.G., Hamburg. This gauge works on the vibrating-wire principle, and the main purpose of the tests was to ascertain whether gauges of this type are suitable for installation in large earth dams. Following a detailed description of the gauge, shown in the section appended, an analysis of the test results is given. The behaviour of the gauge was checked in the following respects: (i) Effect of temperature variation on accuracy; (ii) response to change of water pressure; (iii) Effect of exterior earth pressure on accuracy; (iv) Response to variations of pore pressure in a clay. In their conclusions, the authors claim that the type of gauge tested represents

a great advantage in the measurement of pore pressure and is almost a perfect element for the purpose; not only does the gauge possess a number of technical advantages over a piezometer but the cost of its installation may also be lower than for a comparable layout utilising piezometers. (Dr. Ing. H. Muhs, Berlin, and D. Campbell-Allen, M.A., *The Journal of The Institution of Engineers, Australia*, Vol. 7, No. 9, September 1955, p. 241, 5 pp., 6 ff.)

Oulu River Development

The Oulu River (Oulujoki) development, Finland, which drains an area of about 23,000 sq. km., utilises in seven plants an aggregate head of 122·5 m. along the 107 km. of its course between Oulu Lake, 900 sq. km. in area and about 25 m. deep, and the Gulf of Bothnia. With the exception of the Merikoski plant, operated by the Oulu Corporation, the development is controlled by Oulujoki Oy (Oulu River Company) and, once completed, will present the following main characteristics:—

Plants:	Merikoski	Jylhämä	Nuojua	Utanen	Pälli	Pyhäkoski	Montta
Operated discharge	—	400	—	—	—	—	—
Head .... m.	10·0	10·6/13·8	21·3	15·5	13·8	32·2	12·0
Maximum Capacity MW	33·0	44·0	72·5	52·5	46·5	109·0	40·5
Average Production million kWh p.a.	185	220	375	270	240	560	210
Beginning of construction work	1939	1946	1949	1952	1949	1941	1952
Beginning of generation	1948	1950	1954	1956	1953	1949	1955

Except Merikoski, operated from a headrace canal, all power houses are built in the river bed and, to ensure connection with the railways, close to the south bank. The Kaplan turbines, three to each completed plant, are all of Finnish design, Sweden, Switzerland and West Germany sharing in the manufacture of the generators. All dams have timber chutes, some of them ice passes and fish ladders, and all are designed as bridges for vehicle traffic. Except at Montta, all foundations rest on the rock which almost everywhere is nearly up to river bed. The article concludes with a brief description of the plants, which include some features of special interest. At Pyhäkoski, the hollow buttress dam involved the placing of 150,000 cu. m. of concrete reinforced by 5,000 tons of steel; the power house itself, largest in size and second in capacity in Finland, stands at the downstream end of a 17 km. stretch of rapids. Jylhämä, the keystone of the system at its upstream end, regulates the flow for all downstream plants; to maintain a supply of 400 cu. m. per sec. during the whole year, the river bed at the outlet of Oulu Lake had to be excavated to an appropriate depth. At Noujua, power house and spillway are flanked by short earthfill dams the core of which consists of a double row of wood piles set into a joint of the concrete foundation. The walls of the joint were first lined with tarred jute fabric, and once the piles were in position the joint was filled with hot bitumen, a procedure which proved very satisfactory. The absence of foundation rock at Montta caused considerable difficulties; these were overcome by setting up an apron of sheet piling, 18 m. long steel piles being rammed to form rectangular chambers from which the earth was excavated, whereupon other steel piles were rammed in the middle of each chamber, and the chamber subsequently filled with concrete. From 1956 on, the aggregate capacity of the fully completed development will amount to about 400,000 kW, and the average yearly production to 2,000 million kWh. An annual production of a further 4,000 million kWh is expected from the Kemi River development, north of the Oulu River, on which preliminary work is in progress. (Dipl. Ing. Ehrhardt Pierau, *Die Wasserwirtschaft*, Vol. 45, No. 4, August 1955, p. 291, 4 pp., 6 ff.)

Cofferdam on Ice Foundation

The cofferdam which is to divert the Skagit River from the construction site of Seattle City Light's Gorge high dam will be founded on ice. This uncommon procedure was resorted to because of the presence in the river bed at the dam site of a pocket up to 160 ft. deep which had been filled over the centuries with an accumulation of sand, gravel, and huge boulders. If not altogether impossible, the setting up of a conventional cofferdam would have been expensive and difficult, since the structure would have to extend through the pocket right down to bedrock. City Light engineers decided instead to freeze the river bed down to bedrock, thus preventing water seepage, and then construct a cofferdam on top of the frozen foundation. The contractors first drilled and cased 6 in. holes to depths of 160 ft. at 4 ft. intervals in a single row across the river bed to create an "ice dam" about 2 ft. thick. About 80 of these freezing points will be required for each phase of the freezing programme, as the cofferdam is to be constructed in two stages, diverting the river first to one side and then to the other. The article concludes with a description of the refrigerating plant required and its mode of operation. (*Electrical World*, Vol. 144, No. 13, Sept. 26, 1955, p. 32, 1 map.)

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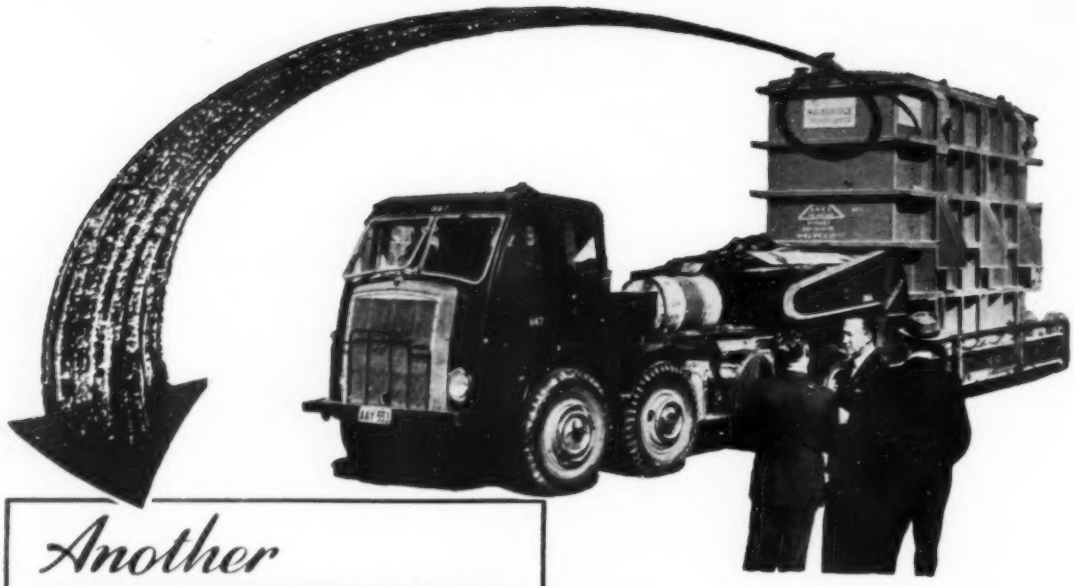

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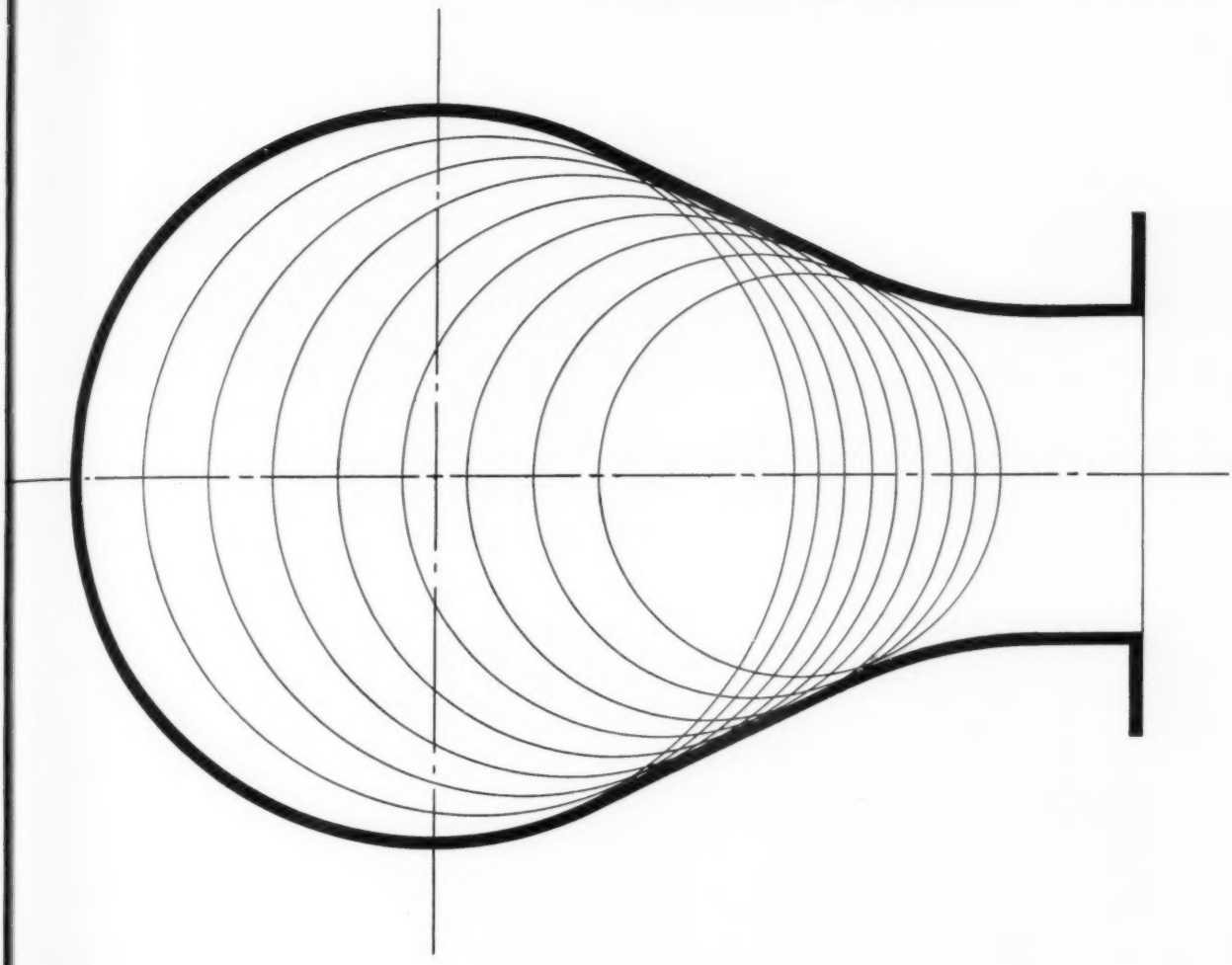

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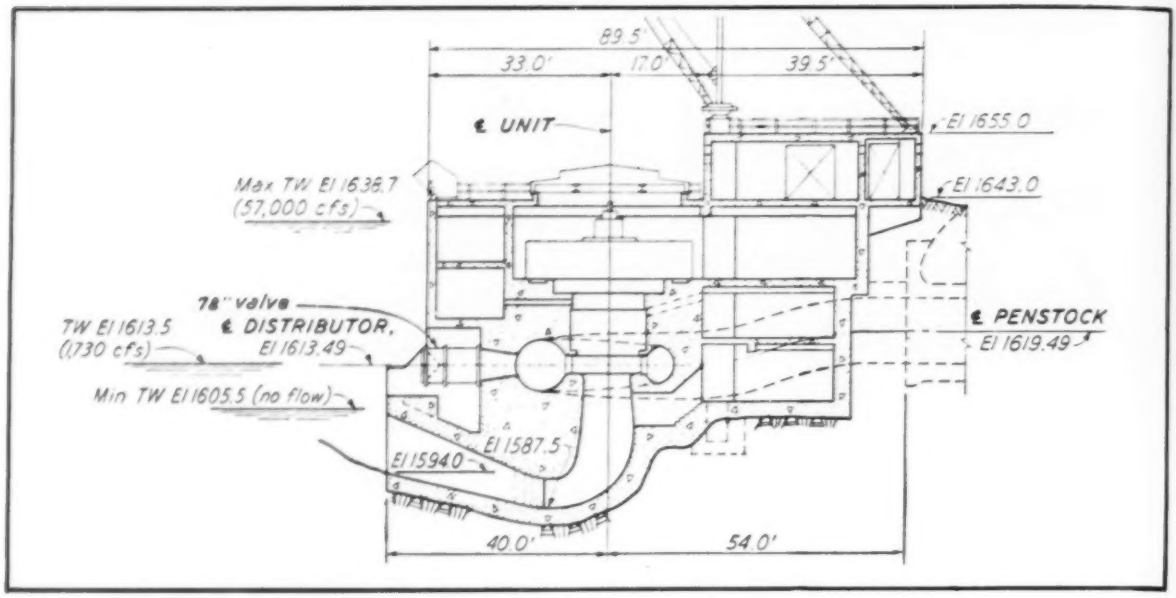
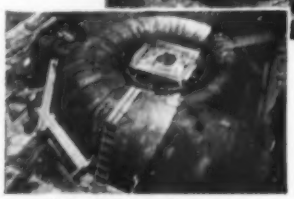
TVA Installs *Another* Leffel Turbine

Nottely Dam Power Plant — a progress report as of the end of 1955



Completely assembled turbine except for riveted scroll case.

Powerhouse excavation and draft tube forms in place.



Assembled scroll case in position from above.

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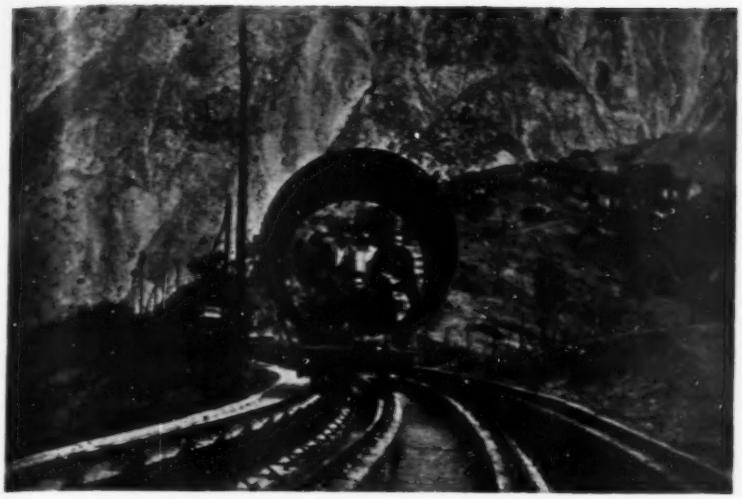

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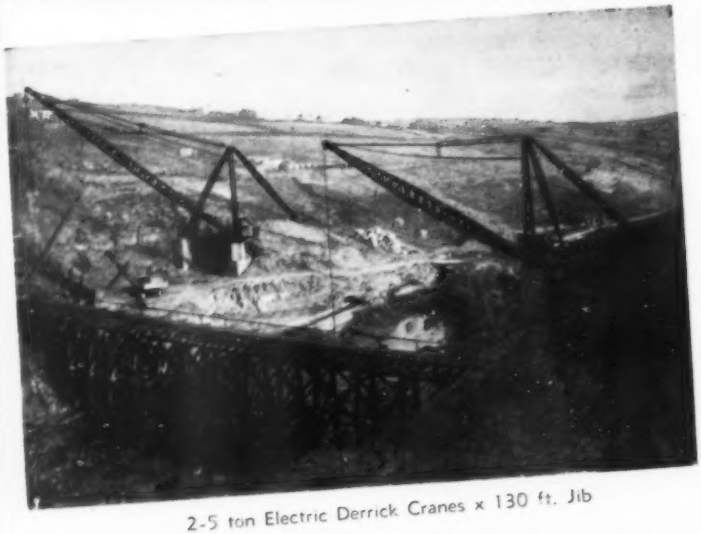

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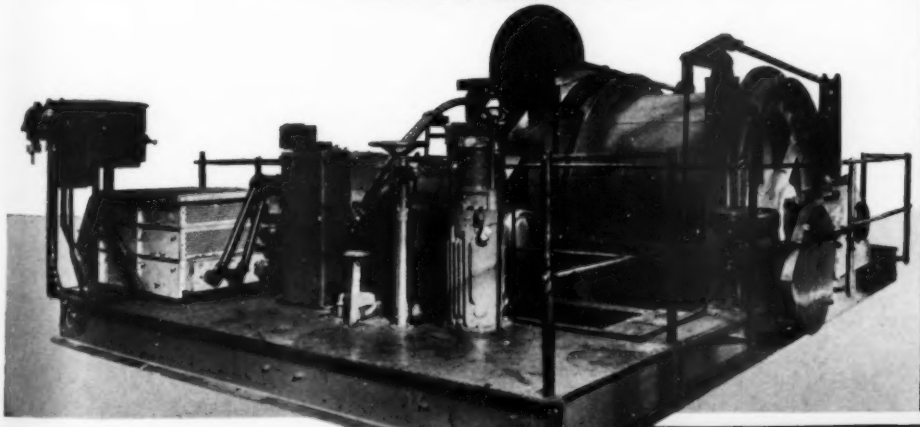

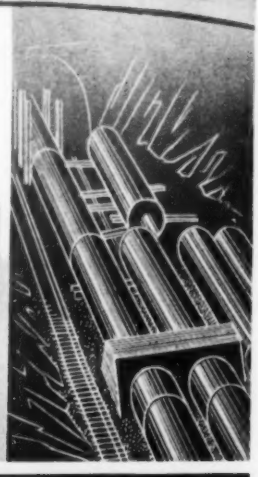

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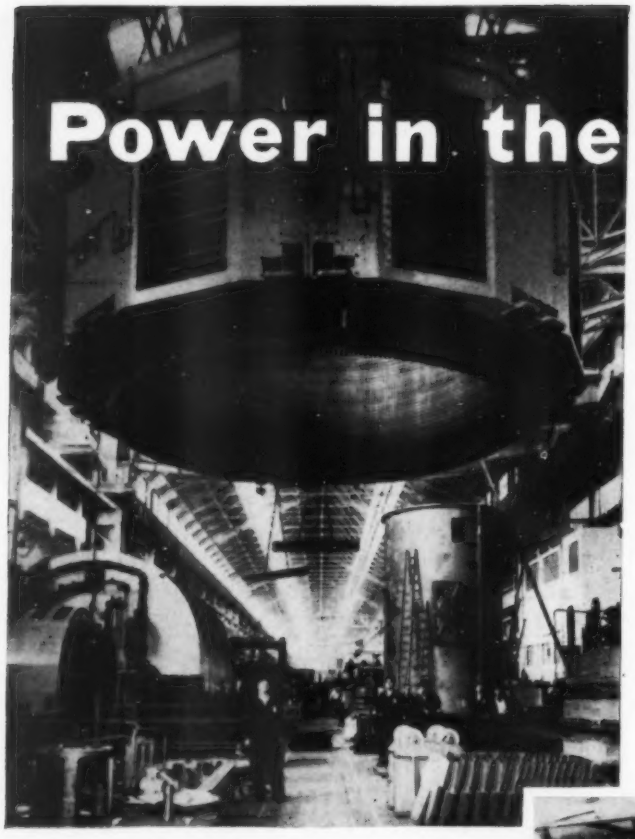

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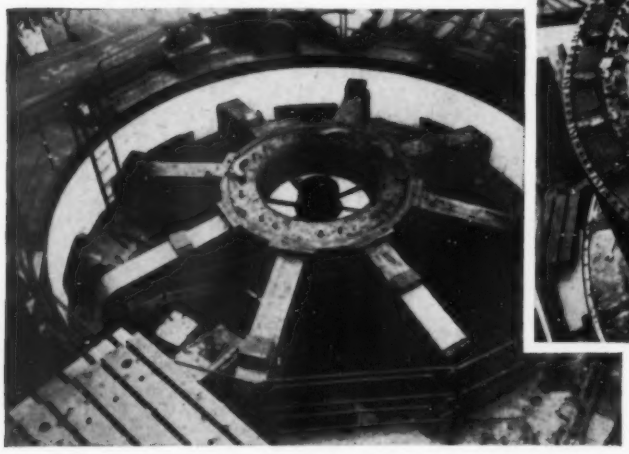

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